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(54) Title: METHOD FOR DETERMINING FEED QUALITY

(57) Abstract

A method for determining a biomechanical property of a feed, the method comprising the steps of: (a) subjecting the feed to infrared radiation to obtain spectral data; and (b) using the spectral data to determine the biomechanical property; whereby, the biomechanical property of the feed is determined on the basis of the bond energies of the chemical constituents of the feed.

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Method for Determining Feed Quality

This invention relates to a method for quantifying biomechanical properties of animal feed based on a correlation between the chemical and biomechanical properties of the feed, and to methods for objectively measuring the quality of animal feed, such as fodders including hay, pastures and forages.

Diet is the major determinant of productivity of an animal. In the livestock industry, animals are farmed for meat, wool and other valuable products. The diet of farmed livestock is largely dictated by man and, given the effect of diet on animal production, it is highly desirable to optimise the diet of livestock to gain maximum benefit from the natural resource.

Feed quality is one variable that has a major impact on animal productivity. In this respect, feed quality affects the amount of feed an animal will consume and the feeding value it gains from the feed consumed. In the case of cattle, sheep and other ruminants, feed quality depends on digestibility, chemical attributes (nutrient composition) and biomechanical attributes (namely how easy it is for an animal to chew the feed during ingestion and rumination).

It is generally accepted that there are constraints on the intake of feed by ruminant animals, that the amount of useful energy obtained by a ruminant animal may fall short of the amount that the animal can potentially use, and that this would result in reduced productivity. For example, the principal constraints to voluntary intake of fodders are resistance of fodder fibre to chewing and digestibility (provided that the intake is not otherwise constrained by low palatability, deleterious secondary compounds, or the inadequacy of essential nutrients). Differences between feeds, such as fodders, in their resistance to chewing are reflected in differences in biomechanical properties, including comminution energy, shear energy, compression energy, tensile strength, shear strength and intrinsic shear strength.

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Hay is a common feed, and its quality is significantly affected by factors such as seasonal differences, haymaking practices and pasture composition. It has been shown in one recent survey that in some years as little as 11% of hay produced was good enough to promote liveweight gain in weaner sheep. This possibility of wide variation in measures of hay quality is a matter of increasing concern, and has given rise to a demand for a method of objective quality assessment.

A hay quality system adopted in the United States of America uses a measure known as relative feed value (RFV) to distinguish between hays of different quality. The RFV is calculated from the dry matter digestibility, which is predicted from acid detergent fibre (ADF) content, and from the dry matter intake, which is predicted from neutral detergent fibre (NDF) content.

The RFV based system suffers from a number of disadvantages. For example, the ADF and NDF contents of fodders are determined by chemical methods which take several days to complete, and thus are expensive in terms of resources.

While objective quality assessment and product specification has become an integral part of the production and marketing in domestic and export markets for the Australian grain, wool, meat and dairy industries, performance-based quality standards are not presently in place for feeds such as hays and other fodders. Consequently;

- (a) the feed buyer cannot be sure of getting value for money, and this is likely to become increasingly important in respect of export markets if other exporting countries are able to guarantee standards for their product;
- (b) the feed producer cannot be sure of getting a higher price for a superior product;

- (c) livestock producers are unable to objectively formulate rations or supplementary feeding regimes to achieve animal production targets; and
- (d) the market for animal feed tends to be unstable.
- Whilst the relationship between biomechanical properties of feed and feed quality is now accepted, there is a need for a convenient, inexpensive and relatively accurate assay method for feed to determine its quality. An accurate determination of feed quality allows for optimisation of feeding regimes and improved animal production for obvious economic gains.
- 10 It is an object of this invention to overcome or at least partially alleviate the aforementioned problems and/or reduce the uncertainties and concomitant problems of the prior art systems for measuring the biomechanical properties of feed and hence determining feed quality.

Thus, the present invention provides a method for determining a biomechanical property of a feed, the method comprising the steps of;

- (a) subjecting the feed to infrared radiation to obtain spectral data;and
- (b) using the spectral data to determine the biomechanical property;

whereby the biomechanical property of the feed is determined on the basis of the bond energies of the chemical constituents of the feed.

The spectral data may be used directly to determine the biomechanical property of the feed. Alternatively, the spectral data may be used to determine another property of the feed and the other property is used to determine the biomechanical property on the basis of a correlation between the other property and the biomechanical property.

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When the biomechanical property is determined via another property, the other property is preferably a chemical property of the feed such as the ADF content or the NDF content or the lignin content.

There is a variety of biomechanical properties of the feed that may be determined. Preferably, the biomechanical properties are selected from the group comprising shear energy, compression energy, comminution energy, tensile strength, shear strength and intrinsic shear strength.

The spectral data may comprise a reflectance spectrum at a combination of wavelengths or over a predetermined range of wavelengths such as 700nm-3000nm, or more preferably 1100nm-2500nm. Preferably, the data obtained for the spectral range of 1850nm-1970nm is disregarded, this being the range over which water reflects strongly.

The spectral data may be recorded at one or more wavelength intervals throughout the spectral range. When the spectral data is a reflectance spectrum over a predetermined range it is preferably measured at 2nm intervals over the range. Of course, if so desired the spectral data may be measured at intervals other than 2nm.

When the spectral data is used to directly determine a biomechanical property, the biomechanical property is preferably determined by comparison of the spectral data with a calibration equation that reflects the relationship between reflectance and the biomechanical property. Preferably, the calibration curve is determined on the basis of laboratory data establishing a correlation between reflectance and the biomechanical property.

Thus, the present invention also provides a method for determining a biomechanical property of a feed, the method comprising the steps of;

(a)	subjecting the feed to infrared radiation to	obtain	spectral	data

(b) comparing the spectral data obtained in (a) with a calibration equation to determine the biomechanical property;

whereby the biomechanical property of the feed is determined on the basis of the bond energies of the chemical constituents of the feed.

- The present invention also provides a method for determining feed quality, the method comprising the steps of;
 - (a) subjecting the feed to infrared radiation to obtain spectral data;
 - (b) using the spectral data to determine a biomechanical property of the feed; and
- 10 (c) using the value of the biomechanical property obtained in step (b) to determine feed quality;

whereby the biomechanical property of the feed and thus the feed quality is determined on the basis of the bond energies of the chemical constituents of the feed.

- In one particular form, the method described immediately above may further comprise the determination of an additional property of the feed. The additional property may vary and preferably is selected from the group comprising the digestibility of the feed *in vivo* or *in vitro*, the ADF content or the NDF content, or the lignin content.
- The present invention is based on research establishing a strong correlation between the bond energies as they relate to the physical structure, and the biomechanical properties of feed. Once this correlation is established the bond energies of the chemical constituents, and in turn the biomechanical properties of the feed, can be determined using infrared spectroscopy. The biomechanical

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properties quantified in this way are useful for accurately determining feed quality.

In this respect, research resulting in the present invention has shown that the biomechanical attributes of feeds such as cereal and legume hays, straws, and mature, dry subterranean clovers are much more strongly related to animal performance than are digestibility or chemical composition of the feeds.

Thus, comminution energy, the energy required to grind or comminute fodder material, has proved to be a very effective indicator of forage consumption constraint (FCC), which is the difference between the quantity of forage an animal should consume to satisfy its capacity to use energy (a theoretical maximum) and the actual voluntary dry matter intake achieved.

Shear energy, the energy required to shear fodder material, and compression energy, the energy required to compress fodder material, are two biomechanical feed characters of fodders that are closely related to comminution energy and which also are good predictors of FCC.

In this respect, feed quality can be assessed in a number of ways. The forage consumption constraint (FCC) is one convenient measure of feed quality and equates to the difference between the quantity of the fodder that the animal would be attempting to consume to satisfy its capacity to use energy (theoretical maximum intake) and the voluntary forage consumption (VFC).

Thus, the present invention also provides a method for determining feed quality, the method comprising the steps of;

- (a) subjecting the feed to infrared radiation to obtain spectral data;
- (b) using the spectral data to determine a biomechanical property of the feed; and

(c) using the value of the biomechanical property obtained in step (b) to determine the forage consumption constraint (FCC) or voluntary feed consumption (VFC) as a measure of feed quality;

whereby the biomechanical property of the feed and thus the feed quality is determined on the basis of the bond energies of the chemical constituents of the feed.

The present invention is based on the finding that variations in biomechanical properties such as shear energy, comminution energy and compression energy are reflected in NIR spectra of fodders. This finding, together with recognition of the value of biomechanical characters for the prediction of FCC (and, in turn, the prediction of voluntary feed consumption (VFC)) makes it possible for quicker, less expensive, more convenient and more reliable prediction of feed quality than hitherto known and predicted.

Accordingly, this invention provides a method of (i) assessing the suitability of a fodder, such as a forage, to meet a required animal performance; or (ii) predicting the VFC of a forage; or (iii) predicting the FCC of a forage, which method comprises subjecting a sample of the forage to NIR radiation and determining the reflectance at selected wavelengths.

It has been found that the biomechanical properties, such as shear and comminution energy values for a given fodder, correlate with the fodder's reflectance of infrared radiation. More specifically, the invention is based on research showing that:

(a) NIR wavelengths at which reflectance (R), namely the second derivative of the logarithm of the inverse of R, correlates significantly with the variation in energy required to shear fodder materials are 1168nm, 1458nm, 1598nm, 1718nm, 1828nm and 2048nm. For the prediction of fodder shear energy (y₁, kJ.m⁻²) the following equation may be used:

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$$y_1 = 19.95 + 10239.46 R_{1168} + 3623.49 R_{1458} - 4255.61 R_{1598} - 5319.88 R_{1718} + 5148.38 R_{1828} + 2452.05 R_{2048}$$

(b) NIR wavelengths at which the second derivative of the logarithm of the inverse of reflectance (R) correlates significantly with the variation in energy required to comminute fodder materials are 1138nm, 2018nm, 2128nm and 2408nm.

For the prediction of fodder comminute energy (y₂, kJ.kg DM⁻¹) the following equation is proposed:

$$y_2 = 231.42 + 18224.74 R_{1138} - 4955.12 R_{2018} - 3005.37 R_{2128} + 4290.18 R_{2408}$$

(c) NIR wavelengths at which the second derivative of the logarithm of the inverse of reflectance (R) correlates significantly with the variation in compression energy are 1268nm, 1588nm, 1728nm, 2278nm. For the prediction of compression energy (y₃, kJ.kgDM⁻¹) the following equation may be used:

$$y_3 = -0.71 - 911.04 R_{1268} + 112.57 R_{1588} - 79.48 R_{1728} - 28.02 R_{2278}$$

(d) NIR wavelengths at which the second derivative of the logarithm of the inverse of reflectance (R) correlates significantly with variation in *in vivo* digestibility of dry matter (DMD) (y₄, %) is 1158nm, 1238nm, 1668nm,
 1908nm, 1918nm, and 2248nm. For prediction of the DMD (y₄, %) of a fodder the following equation is proposed:

$$y_4 = 46.62 + 8162.72 R_{1158} - 8799.69 R_{1238} + 1249.01 R_{1668} + 519.46$$
 $R_{1908} - 367.08 R_{1918} - 161.84 R_{2248}$

(e) NIR wavelength at which the second derivative of the logarithm of the 25—inverse of reflectance (R) correlates significantly with variation in in vitro

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digestibility of dry matter (IVDMD) is 1698nm, 1748nm, 1908nm, 1918nm and 2158nm. For prediction of the DMD (*in vitro*) of a fodder the following equation is proposed:

$$y_5 = 63.43 - 2186.89 R_{1698} - 1491.99 R_{1748} + 981.30 R_{1908} - 556.01 R_{1918} + 2003.05 R_{2158}$$

Accordingly, in a preferred method according to this invention, the infrared wavelengths at which reflectance is measured comprise one or more of the following: 1168nm, 1458nm, 1598nm, 1718nm, 1828nm, 2048nm, 1138nm, 2018nm, 2128nm, 2408nm, 1268nm, 1588nm, 1728nm, 2278nm, 1158nm, 1238nm, 1668nm, 1908nm, 2248nm, 1698nm, 1748nm, 1918nm and 2158nm.

It will be understood that the foregoing are wavelengths at which the strongest correlations have been observed, and the possibility of useful correlations being observed at other wavelengths are highly likely.

Essentially, it can be shown that in the same way that a decrease in comminution energy is reflected by a decrease in forage consumption constraint, there is also a linear relationship between comminution energy or shear energy and the consumption constraint of a fodder. Thus, the use of NIR spectra, in conjunction with the equations detailed at paragraphs (a) to (e) above, permits estimation of the VFC of a fodder, which together with estimates of digestibility (conveniently obtained from NIR spectra) can be expected to provide a valuable basis for performance-based quality standards for fodders.

It is to be appreciated that the intention of this invention is to offer a quick, reliable and relatively inexpensive means of obtaining information from which the fodder producer and user, such as purchaser, might make informed judgements about the market value of a given fodder sample relative to alternatives, and of its suitability for a particular-purpose.

Conceivably, fodder quality predictions obtained by the method of this invention could be a useful component of, or used in conjunction with, for example, Decision Support Software (DSS) packages designed to assist livestock management.

It is further envisaged that by combining NIR measurements made by a remote sensing system, such as Landsat, with data from a Geographical Information System, the invention will provide a means of making reliable predictions of pasture quality. These predictions, together with predictions of feed intake and animal performance, should then provide a useful basis for strategies of supplementary feeding to improve performance in grazing ruminants.

The present invention also provides for a spectrometer configured to determine biomechanical properties and/or quality of feed according to the methods of the present invention. Preferably, the spectrometer includes a data processing means which enables the spectrometer to receive a feed sample and quantify either or both the biomechanical properties of the feed and the quality of the feed. In one particular form the data processing means includes a calibration equation to facilitate the determination of the feed quality or biomechanical property.

The invention will now be described with reference to the following examples. The description of the examples is in no way to limit the generality of the preceding paragraphs.

EXAMPLES

The energy of molecular vibrations correspond to the energy of the infrared spectrum of the electromagnetic spectrum, and these molecular vibrations may be detected and measured in the wavelength range of the infrared spectrum. Functional groups in molecules have vibration frequencies that are characteristic of that functional group and that are within well-defined regions of the infrared spectrum.

For organic compounds the principal analytical features of the near infrared (NIR) spectrum are due to absorbance of radiant energy by bonds between hydrogen, carbon, nitrogen, oxygen or with sulphur, phosphorus and metal halides. When organic compounds are irradiated with infrared radiation at wavelengths between 700 and 3000nm part of the incident radiation is absorbed and the remainder is reflected, refracted or transmitted by the sample. Most quantitative reflectance analyses are made in the wavelength range of 1100 to 2600nm. The amount of energy absorbed or diffusely reflected at any given wavelength in this wavelength range is related to the chemical composition of the organic compound. NIR spectroscopy uses detectors to measure the amount of radiation that is diffusely reflected by the irradiated sample.

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NIR spectroscopic analysis is an analytical procedure calibrated to a primary reference method. Calibration in NIR spectroscopy (NIRS) relies on similarities among the spectra, and analytical properties of interest in the reference samples. In this example the analytical properties of interest were the biomechanical characters of forages, and the procedure that was adopted in this example was as follows:

a) prediction of biomechanical characters of a range of grasses using NIR spectroscopy was established by developing a calibration equation(s) from laboratory determined values of a set of reference samples.

- b) validation of the equation(s) either by using laboratory determined values of a separate set of samples, or by a cross-validation procedure using the laboratory determined values of the reference samples.
- using the NIRS-predicted values for biomechanical characters of the forages
 and for digestibility of the forages, forage consumption constraint (FCC) was predicted, and in turn voluntary feed consumption (VFC) was predicted.
 - d) the predicted FCC and VFC were compared with actual data from groups of animals fed each of these forages.
- 10 Example A: Developing a calibration equation to predict biomechanical properties of herbage:

The samples used in this example were a range of varieties of *Panicum spp.* harvested at a range of plant maturities throughout the growing season (Table 1). Each of the samples was dried and chaffed, and then fed to groups of sheep (8 sheep per group) which were penned individually, to determine *in vivo* dry matter digestibility (DMD), VFC and FCC. Samples of the hays were stored for laboratory analyses.

Biomechanical properties of the forages were determined using published 20 methods; the energies required to shear or compress the forages according to Baker, Klein, de Boer and Purser (Genotypes of dry, mature subterranean clover Proceedings of the XVII International Grassland differ in shear energy. Congress 1993. pp 592-593.) and the energy required to comminute the forages according to Weston and Davis (The significance of four forage characters as 25 constraints to voluntary intake. Proceedings of the Third International Symposium on the Nutrition of Herbivores, Penang, 1991). In vitro digestibility of dry matter (IVDMD) was determined by the pepsin-cellulase technique as modified by Klein and Baker (Composition of the fractions of dry, mature subterranean clover digested in vivo and in vitro. Proceedings of the XVII 30 International Grassland Congress 1993. pp593-595.).

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There are several ways to process samples for NIRS analysis, and in this example the samples were ground through a cyclone mill with a 1 mm screen and equilibrated at 25°C for at least 24h before NIRS analysis. The samples were scanned by a monochromating near infrared reflectance spectrophotometer (Perstorp NIRS 6500) and the absorption spectra recorded for the range 1100 to 2500nm at 2nm intervals. The spectral range 1850 to 1970nm, where water absorbs strongly, was disregarded in further analysis of the spectral data.

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10 For NIRS analysis the samples were divided into two groups: one group to be used as a 'calibration' set to establish a prediction equation, and a second group, the 'validation' set, to be used to validate the prediction equation. There are a number of ways to select the samples for each set. In this example the samples were ranked according to each of the characters that were to be predicted and every other sample was selected for the calibration set (33 samples) and the validation set (32 samples).—Thus, for each character that was evaluated, a different selection was made from the 65 samples to establish the respective calibration and validation sample sets.

The ranges, mean, median and variation in the laboratory-determined values for each of the characters of interest in the calibration and validation sets are listed in Table 2.

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The software for scanning, mathematical processing and statistical analysis were supplied with the spectrophotometer by the manufacturers. The spectral data were transformed by taking the second derivative of the logarithm of the inverse of the reflectance (R) at each wavelength (d" log (1/R)). The similarities amongst the spectra (Figure 1) of the samples in the validation and calibration sets were determined using principal components scores to rank the spectra according to the Mahalanobis distance from the average of the spectra. The Mahalanobis distance values were standardized by dividing them by their average value, and were denoted 'global'-H values (Table 3).

Calibration equations were developed using the calibration samples by regressing the data from the laboratory analyses of each biomechanical property against the corresponding transformed spectral data using the following mathematical methods:

- a) Stepwise linear regression
- b) Step-up linear regression
- c) Principal components regression (PCR)
- 10 d) Partial least squares regression (PLS), and
 - e) Modified partial least squares regression (MPLS).

Stepwise calibrations were developed for each calibration set of samples using the mathematical treatments of the spectral data 2,2,2; 2,5,5; 2,10,5; and 2,10,10; where the first number denotes that the second derivative was used, the second indicates that second derivatives of the spectral data (determined at 2nm intervals) were taken at intervals of 4, 10 or 20nm, and the third indicates that the function was smoothed using the 'boxcar' method over intervals of wavelength of 4, 10, or 20nm (Table 4a). Likewise step-up calibrations were developed for each calibration set with up to 6 terms in each calibration equation using mathematical treatments 2,2,2; 2,5,5; 2,10,5; and 2,10,10 (Table 4b). Calibrations developed for each calibration set using principal components regression, partial least squares regression, or modified partial least squares regression each were developed using mathematical treatments 2,5,5 and 2,10,10 (Table 4c).

In developing the calibration equations in the stepwise and step-up regressions, only wavelengths with partial F-statistic of more than 8 were accepted for the models.

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For each calibration using each calibration set the following calibration statistics were determined:

- a) Squared multiple correlation coefficient (R²), an indication of the proportion of the variation in the calibration set that is adequately modelled by the calibration equation.
- b) The standard error of calibration (SEC) together with its confidence interval (± CL), which is the standard deviation for the residuals due to difference between the laboratory determined (reference) and the NIR predicted values for samples within the calibration set

Once the calibration equations were developed, each equation was validated by using it to predict the respective biomechanical property values for each sample in the validation sample set. For each calibration equation the following validation statistics were determined:

- a) Simple linear correlation coefficient (r²) between the laboratory determined and NIR predicted values.
- 15 b) The bias (or systematic error) in the regression relationship between the laboratory determined (reference) and NIR predicted values.
 - c) The confidence limits of the bias in the regression relationship between the laboratory determined (reference) and NIR predicted values.
- d) The standard error of prediction, corrected for bias (SEP(C)), which represents the unexplained error of the prediction, the deviation of the differences between laboratory determined and NIR predicted values.
 - e) The coefficient of determination, or slope (β) , and y-intercept (α) of the linear regression relationship between the laboratory determined and NIR predicted values.
- 25 f) The residual standard deviation (RSD) of the linear regression relationship between the laboratory determined and NIR predicted values.

In addition, the calibration equations were validated using a procedures of cross-validation. These are procedures where every sample in the calibration set was used once for prediction, and the standard error of validation corrected for bias (SEV(C), for stepwise and step-up regressions) and cross-validation (SECV, for multivariate regressions)-can be determined.

Calibration equations for each biomechanical character were selected using the following criteria:

- a) Lowest partial F-ratio, highest R², lowest SEC and, for PCR, PLS and MPLS, lowest SEV(C) (or, for multivariate regressions, SECV)
- b) Highest r^2 , lowest bias and |bias| < bias confidence limit, lowest SEP(C), β closest to 1.0, α closest to 0, and lowest RSD. As well, SEP(C) was compared with the standard error of laboratory determined values amongst all 65 samples, listed in Table 5.

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Calibration equations were similarly established to predict *in vivo* digestibility and *in vitro* digestibility. The coefficients for each wavelength in the selected calibration equations from stepwise or step-up regression analyses are listed in Table 6a, and those from multivariate analyses are listed in Table 6b.

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Simple linear correlation coefficient (r²) between the laboratory determined and NIR predicted values for each of the biomechanical characters (energies required to shear, comminute or compress) and digestibility of dry matter determined *in vivo* or *in vitro* of the samples in the validation set are shown in Figures 2a, 2b, and 2c. The NIR predicted values are predicted using calibration equations that best met the criteria listed above.

Example B: Prediction of FCC and VFC using NIR determinations of energy required to shear and *in vivo* digestibility:

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To demonstrate the prediction of voluntary feed consumption using NIR determined values for a biomechanical character and digestibility of forages, samples of *Panicum spp*. hay were selected which were common to both of the validation sample sets used to establish the NIR prediction equations for energy required to shear and *in vivo* digestibility. The hays represented the range of varieties in the sample set, and are listed in Table 7. The samples were scanned by the same spectrophotometer that was used to establish the

calibration equations, and the absorption spectra were recorded in the range 1100 to 2500nm at 2nm intervals. Values for energy required to shear and *in vivo* digestibility were predicted from calibration equations (Tables 4a, 4b and 4c) using the recorded spectral data.

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These values then were used to estimate FCC from the relationship between biomechanical character(s) and FCC of the range of forages used by Weston and Davis (1991). Energy required to shear the forages used by Weston and Davis was determined according to Baker *et al.* (1993). The relationship between the energy required to shear these forages (kJ/m²) and FCC (g organic matter (OM) / d / kg metabolic body weight (MBW)) was described by the relationship:

Energy required to shear (x) = -26.13 + 5.53 (FCC (y)) where R = 0.92; RSD = 8.70; N = 13; P < 0.0001.

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FCC from this relationship and *in vivo* digestibility predicted by NIR were then used to estimate VFC, as the difference between the animal's capacity to use energy (as defined by Weston and Davis, 1991) and FCC. These data are summarised in Table 8.

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VFC predicted in this way explained most of the variation in actual VFC (R = 0.87; RSD = 5.04; P = 0.023) (Figure 3).

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State of an article	stage of maturity		late bloom (9 weeks' regrowth)	late bloom (13 weeks' regrowth)	late bloom (4 weeks' regrowth)	mid bloom (1 month's regrowth)	mid bloom (1 month's regreeth)	mid bloom (10 weeks' regrowth)	mid bloom (8 weeks' regrowth)	vegetative regrowth (29 days")	lete bloom	late bloom (4 weeks' regrowth)	late bloom (19 weeks' regrowth)	lete bloom (14 weeks' regrowth)	mid bloom (9 weeks' regrowth)	mid bloom (8 weeks' regrowth)	vegetative regrowth (28 days')	early bloom (1 month's regrowth)		ate bloom (14 weeks' regrowth)	late bloom (4 weeks, recently)	(Introduction of the control of the	mid bloom (8 weeks' regrowth)			vegetative regrowth (31 days.)		mid bloom (1 month)s regrowth)		mid bloom (4 weeks' regrowth)			_	ind bodin (10 weeks' regrowth) (n
Process undergone		4.4		oned end challed	dried and chaffed	dried and chaffed				Gried and chaffed		_		_		_	_	Greed eard charled	dried end chaffaut		dried and chaffed		dried and chaffed	dried and chaffed		dried and chaffed v		Gried and chaffed in		oned and chaffed n	defend and alteriary			_
Partof	plant	Jehren	1			ic Lo		a Louis		le l	- T	E 3							serfal		- jatua			ertei		eertel			- Johnson		- lefter			
Common name		Makarikari orasa	Makerikari crass	Makerikeri mese	Makeriked mees	Makedised press	Makenkar grass	Makeriked grass	Makarikari prass	Makarikari press	Makeriked grees	Makerikeri prese	Makedied organ	Maharitan grass	Makedied and	Makeriked grees	Mekarikari grasa		Makarikari grass		Makarikeri grass	Maharikan masa		Makerikari grass		Makarikari grase	Makeriked green	_	Makarikari crass		Guinea grass			
Variety		Bambetsi	Bambatsi	Bernbatai	Bambata	Bernhahel	Bambatal	Bembets	Bambatal	Kabulabula CPI 18798	Kabulabula CPI 16796	-	_	CPI 18796	CPI 18708	CPI 18798	}		Burnett		Burnett	Burnett		Burnett		מתופנו	Burnett		Burnett				Coloniao	
Species		coloratum	coloratum	coloratum	coloratum	coloratum	coloretum	coloretum	coloratum	coloratum	coloratum	coloratum	coloretum	coloratum	coloratum	coloratum		-	_		Makerikariense		•	coloratum var		•	-			Jense			meximum C	
Genus		Panlcum	Panicum	Panicum	Penlcum	Panlcum	Panlcum	Penicum	Penlcum		_	Penicum	_	_	Penkum	<u> </u>	Penlaum	_	Panlcum	Danim	_	Panlcum	_	Pankcum	Denicam		Panicum c		Penlcum c	_	-		remoner	

Description of herbage used in this example.

-1

early bloom - regrowth early bloom - regrowth mid bloom - regrowth mid bloom - regrowth mid bloom - regrowth mid bloom - regrowth lete bloom - regrowth mid bloom - regrowth lete bloom - regrowth mid bloom - regrowth mld bloom - regrowth vegetative regrowth vegetative regrowth vegetative regrowth repetative regrowth vegetative regrowth Regrowth vegetative regrowth regrowth regrowth early bloom (10 weeks' regrowth) early bloom (1 month's regrowth) vegetative regrowth (1 monthie) vegetative regrowth (1 monthis) mid bloom (13 weeks' regrowth) mid bloom (14 weeks' regrowth) mid bloom (15 weeks' regrowth) mid bloom (13 weeks' regrowth) mid bloom (11 weeks' regrowth) mid bloom (1 month's regrowth) mid bloom (10 weeks' regrowth lete bloom (4 weeks' regrowth) mid bloom (4 weeks' regrowth) mid bloom (8 weeks' regrowth) vegelative regrowth (8 weeks') mid bloom (4 weeks' regrowth) regetative regrowth (32 days') vegetative regrowth (4 weeks') regetative regrowth (4 weeks") vegetative regrowth (8 weeks') late bloom (6 weeks' regrowth) regetative regrowth (28 days.) regelative regrowth (33 days') vegetative (8 weeks' regrowth) vegetative regrowth (4 weeks') vegelative regrowth (28 days') vegetative regrowth (32 days') Stage of maturity mid bloom (1 month)s) 75 days' regrowth 54 days' regrowth 88 days' regrowth Process undergone dried and chaffed dried and chalfed dried and chaffed dried and challed dried and challed dried end cheffed dried and charled dried and chaffed Parto e ortal # # # # # # # # a ortal Berta 100 Berta aporta serle 百里 Bertal Serial Serial Common name Guines press **Guinea** grass Guines grass Guines grass Guines grass Guinea grass Guines grass Guines grass Guines grass Guines grass **Guines** grass Guines grass Guhnes grass Guines grass **Green Panic Green Parib** Green Panlo Green Panlo Green Panlo Green Pank **Green Pank** Green Panio **Green Panic Green Panlo Green Penic** Green Parish Variety Coloniao Coloniso Coloniso Coloniao Coloniao Coloniac Pete TeaT E Text TE I Hem Petre TEST EE TEL meximum ver. Inchogiume maximum ver. trichoglume meximum ver. Irichoglume maximum var. Inchogiume maximum ver. Irichoglume meximum ver, inchogiume meximum ver. Inchogiume meximum ver. Urchoglume meximum ver, trichogiume meximum ver. Inchogiume maximum var. Irichogiume meximum ver. Irichogiume meximum ver. Inchogiume maximum var. Inchogluma 8pecies maximum var. meximum meximum meximum maximum meximum meximum meximum maximum meximum meximom maximum meximum meximum meximum maximum (cont'd) Penicum Penicum Penlcum Panicum Penicum Panlcum Panicum Penlcum Penlcum Panlcum Penlcum Panicum Penlcum Panicum Penlcum Penicum Panlcum Penicum Penlcum Penicum Panlcum Panicum Penicum Penicum Penicum Panlcum Panicum Panicum Penlcum Panlcum Penicum

Description of herbage used in this example.

Table 1.

Table 2. Summary statistics for each calibration and validation set

	Energy required to shear	Energy required	Energy required	Digestibility of	Digestibility of di
		to comminute	to compress	dry matter in vivo	matter in vitro
!	(kJ/m²)	(kJ/kg DM)	(kJ/kg DM)	(%)	(%)
Calibration set	7	Energy req	uired to shear		
mean	15.10				
	15.48	134.9	3.70	55.7	53.3
median	15.17	133.8	3.65	56.0	55.1
maximum	20.95	216.5	4.39	64.0	63.0
minimum	10.80	72.5	3.25	43.0	39.8
standard deviation	2.572	37.50	0.265	5.73	6.97
Validation set					0.37
mean	15.43	130.9	3.78	55.6	52.7
median	15.20	128.3	3.75	56.5	53.3
maximum	20.43	205.2	4.24	64.0	63.0
minimum	10.94	54.5	3.34	47.0	40.1
standard deviation	2.444	37.50	0.229	5.36	7.01
	e e e e e e e e e e e e e e e e e e e	Energy require	d to comminute		
Calibration set	1				
mean	15.01	133.1	3.69	55.7	52.8
median	14.76	129.5	3.70	57.0	54.7
maximum	19.97	216.5	4.18	64.0	
minimum	10.80	54.5	3.25	43.0	63.0
standard deviation	2.444	38.82	0.227	5.64	39.8 7.06
'alidation set				3.57	7.00
mean	15.92	132.9	3.79	55.6	53.2
median	15.97	130.2	3.79	55.5	53.2 54.7
maximum	20.95	205.2	4.39	64.0	62.5
minimum	11.46	60.7	3.34	47.0	40.9
standard deviation	2.490	36.20	0.263	5.47	6.92
ruger breen geware	1. 1. 基础的基本 4. 4.	Energy require	d to compress	Elevision	
alibration set					
mean	•	128.1	3.74		53.8
median	15.07	128.4	3.72	57.0	54.7
maximum	19.97	204.0	4.39	64.0	63.0
minimum	10.80	54.5	3.25	47.0	39.8
standard deviation	2.477	38.00	0.261	5.15	6.64
alidation set	•				
mean 	15.64	138.0	3.74	55.0	52.2
median	15.42	132.5	3.72	54.5	54.5
maximum	20.95	216.5	4.24	64.0	62.0
minimum	11.46	60.7	3.34	43.0	40.1
standard deviation	2.530	36.39	0.240	5.87	7.26
		Digestibility of de	y matter in vivo		
alibration set					
nean	15.14	133.9	3.74	55.5	53.1
nedian	15.17	128.4	3.72	56.0	55.1
maximum	20.95	216.5	4.24	64.0	63.0
ninimum	10.80	60.7	3.25	43.0	40.1
standard deviation	2.528	36.39	0.247	5.73	7.33
ilidation set					
nean	15.78	132.1	3.75	55.7	52.9
nedian	15.20	134.7	3.72	56.5	54.4
naximum	20.37	205.2	4.39	64.0	63.0
ninimum	10.94	54.5	3.34	47.0	39.8
tandard deviation	2.446	38.70	0.255	5.36	6.63

Table 2 (cont'd). Summary statistics for each calibration and validation set

	Energy required to shear (kJ/m²)	Energy required to comminute (kJ/kg DM)	Energy required to compress (kJ/kg DM)	Digestibility of dry matter in vivo (%)	Digestibility of dry matter in vitro (%)
a ngjerig, akejatajah		Digestibility of dr	y matter in vitro	rrie entitioner	e je sakaje
Calibration set					
mean	14.70	131.3	3.75	55.6	53.0
median	14.34	129.3	3.71	56.0	54.7
maximum	19.36	216.5	4.39	64.0	63.0
minimum	10.80	54.5	3.25	43.0	40.1
standard	2.235	42.58	0.241	5.78	6.94
deviation	•		•		
Validation set					
mean	16.19	134.6	3.74	55.6	53.0
median	16.16	133.8·	3.74	56.0	54.7
maximum	20.95	194.8	4.24	64.0	63.0
minimum	10.94	65.7	3.34	47.0	39.8
standard	2.538	31.84	0.260	5.33	7.05
deviation					

Table 3. Mahalanobis distances

	Mean	Median	Range
For full sample set:	0.655	0.623	0.203 - 1.983
For calibration sets for: Energy required to shear	0.588	0.549	0.171 - 1.646
Energy required to comminute	0.718	0.676	0.350 - 1.553
Energy required to compress	0.757	0.760	0.188 - 1.440
Digestibility of dry matter in vivo	0.673	0.634	0.389 - 1.547
Digestibility of dry matter in vitro	0.645	0.574	0.185 - 1.178

Table 4a. Calibration and validation statistics

al leth taywa kiğhalı ilik k	Energy rec	uired to sh	ADV ST. Briss	
	31.3	Stepwis		
	2,2,2	2.5.5	2,10,5	2,10,10
Lowest partial F-ratio		6.18	8.27	
R ²	0.798	0.787	0.795	4.70
SEC	1.155	1.188	1.166	0.780
SEC CL	1.493	1.535	1.507	1.207
SEV(C)	1.230	1.306	1.273	1.560
r ² ` ′	0.368	0.625	0.520	1.322
Bias	0.690	0.710	0.700	0.495
Bias CL	1.484	1.527	1.498	0.720
SEP (C)	1.500	1.540	1.520	1.551 1.570
Slope	0.604	0.617	0.598	· · · -
Intercept	6.340	5.440	5.640	0.758
R.S.D.	1.627	1.627	1.484	3.710 1.476
Bias - Bias CL	-0.794	-0.817	-0.798	
Bias < Bias CL?	Yes	Yes	Yes	-0.831 Yes
number of terms	6	5	5	
		d to commi	nute	<u>6</u>
		Stepwise I	Regression	- Production and Colors
	2,2,2	2,5,5	2,10,5	2,10,10
Lowest partial F-ratio	5.54	4.45	16.55	10.89
R ²	0.910	0.802	0.818	0.831
SEC	11.626	17.281	16.546	15.980
SEC CL	1.493	1.535	1.507	1.560
.SEV(C)	13.103	18.040		17.100
r ²	0.363	0.429	0.374	0.213
Bias	6.980	10.370	9.930	9.590
Bias CL	14.941	22.209	21.264	20.537
SEP (C)	15.110	22.460	21.510	20.770
Slope	0.530	0.575	0.607	0.417
Intercept	58.300	48.900	48.600	74.600
R.S.D.	28.900	27.360	28.650	32.120
Bias - Bias CL	-7.961	-11.839	-11.334	-10.947
Bias < Bias CL?	Yes	Yes	Yes	Yes
number of terms	6	3	4	4
Ener	gy require	d to compre	38	
		Stepwise R	egression	
·	2,2,2	2,5,5	2,10,5	2,10,10
Lowest partial F-ratio	5.05	4.44	7.90	16.19
R ²	0.784	0.500	0.525	0.534
SEC	0.121	0.209	0.204	0.202
SEC CL	1.493	1.535	1.507	1.560
SEV(C)	0.135	0.224	0.217	0.215
r ²	0.069	0.113	0.008	0.067
Bias	0.070	0.130	0.120	0.120
Bias CL	0.156	0.269	0.262	0.260
SEP (C)	0.160	0.270	0.270	0.260
Slope	0.180	-0.080	0.314	0.211
Intercept	3.060	4.030	2.580	2.960
R.S.D.	0.229	0.229	0.227	0.232
Bias - Bias CL	-0.086	-0.139	-0.142	-0.140
Bias < Bias CL?	Yes	Yes	Yes	Yes
number of terms	6	4	4	4

Table 4a (cont'd)

Dig s	tibility of:	dry matter	in vivo	Artinte <mark>v</mark> ij
		Stepwis	Regression	
	2,2.2	2,5,5	2,10,5	2,10,10
Lowest partial F-ratio	7.63	20.68	4.28	6.08
R ²	0.934	0.917	0.914	0.921
SEC	1.107	1.236	1.258	1.207
SEC CL	1.493	1.535	1.507	1.560
SEV(C)	1.215	1.368	1.341	1.284
12	0.654	0.881	0.878	0.876
Bias	1.070	0.890	0.910	0.900
Bias CL	0.156	0.269	0.262	0.260
SEP (C)	2.320	1.940	1.980	1.960
Slope	0.705	0.878	0.840	0.827
Intercept	16.500	6.690	8.640	9.340
R.S.D.	3.153	1.852	1.873	1.888
Bias - Bias CL	0.914	0.621	0.648	0.640
Bias < Bias CL?	No	No	No	No
number of terms	6	6	6	- 5
Digest	ibility of d	ry matter i		
_			Regression	
	2,2,2,1	2,5,5	2,10,5	2,10,10
Lowest partial F-ratio	7.68	11.84	4.33	6.31
R ²	0.935	0.933	0.915	0.922
SEC	1.808	1.751	2.052	1.974
SEC CL	1.493	1.535	1.507	1.560
SEV(C)	1.984	1.981	2.186	2.100
7	0.699	0.847	0.743	0.736
Bias.	1.080	1.050	1.230	1.180
Bias CL	2.324	2.250	2.637	2.537
SEP (C)	2.340	2.280	2.670	2.570
Slope	0.839	0.962	0.775	0.763
Intercept	8.790	1.650	12.200	12.700
R.S.D.	3.805	3.794	3.805	2.719
Bias - Bias CL	-1.244	-1.200	-1.407	-1.357
Bias < Bias CL?	Yes	Yes	Yes	Yes
number of terms	6	5	6	5

Table 4b. Calibration and validation statistics (Step-up regression)

					Energy	Energy required to choor	ohoar					
		S	Step-up Regr	-up Regression 2,2,2					Step-up Red	Step-up Regression 2.5.5		
	1 term	2 terms	3 terms	4 terms	5 terms	6 terms	f term	2 terms	3 terms	4 terms	5 larms	6 torme
Lowest partial F-ratio	29.33	13.83	6.65	5.29	5.89	3.23	25.70		5.71	1.60	4 92	2
R²	0.470	0.625	0.684	0.725	0.766	0.784	0.436	3 0.663	0.709	0.715	0.778	0.792
SEC	1.873	1.575	1.445	1.349	1.244	1.196	1.932	1.492	1.387	1,373	1.211	173
SEC CL	2.420	2.035	1.867	1.743	1.608	1.546	2.497		1.792	1.774	1.565	1516
SEV(C)	1.973	1.672	1.561	1.476	1.390	1.318	2.022	1.571	1.476	1.470	1.357	1319
2	0.371	0.344	0.310	0.205	0.202	0.168	0.375	5 0.531	0.557	0.557	0.631	0.635
Blas	1.120	0.950	0.870	0.810	0.775	0.720	1.160	0.900	0.830	0.820	0.730	0 700
Bias CL	2.407	2.024	1.857	1.734	1.599	1.537	2.483	1.917	1.783	1.765	1.556	1 507
SEP (C)	2.430	2.050	1.880	1.750	1.620	1.550	2.510	1.940	1.800	1.780	1.570	1 520
Slope	90.	0.795	0.784	0.598	0.549	0.498	0.643	909.0	0.616	0.633	0.644	0.633
Intercept	-0.120	3.030	3.290	6.090	6.950	7.790	5.390	5.790	5.560	5.270	5.050	5 170
A.S.D.	1.896	1.803	1.73	1.769	1.732	2.058	1.891	1.806	1.698	1.658	2317	1 945
	-1.287	-1.074	-0.987	-0.924	-0.824	-0.817	1.323	3 -1.017	-0.953	-0.945	.0 826	.0.807
Blas < Blas CL?	Yes	Yes	Yes	Yes	Yes	Yes	SeY.	Yes	Yec	\ \ \	200	20.0
					Energy rec	Energy required to comminute				3	- 63	res
		S	Step-up Regr	-up Regression 2,2,2					Slep-un Ren	Slap-un Berresslon 2 5 5		
	1 term	2 terms	3 terms	4 terms	5 terms	6 terms	1 term	2 terms	3 farms	4 forms	5 torme	9
Lowest partial F-ratio	81.33	12.82	9.62	6.10	6.71	2.92	67.30	9.96	2.73	4 91	5 OB	4 26
R ²	0.715	0.794	0.840	0.864	0.887	0.894	0.974		0.755	0.782	0840	0 830
SEC	20.719	17.629	15.538	14.330	13.061	12.620	22.149	19.757	19.213	18.105	16921	15 083
SECCL	2.420	2.035	1.867	1.743	1.608	1.546	2.497	1.928	1.792	1.774	1.565	1.516
SEV(C)	21.511	18.353	16.378	15.230	13.967	13.633	22.769	9 20.547	20.096	19.092	18.262	17.484
~	0.322	0.424	0.421	0.411	0.371	0.373	0.183	0.199	0.148	0.099	0.114	0.098
Bias	12.430	10.580	9.320	9.600	7.840	7.570	13.290	0 11.850	11.530	10.860	10.150	9 590
Bias CL	26.627	22.656	19.969	18.416	16.785	16.219	29.465	5 25.391	24.692	23.268	21.746	20.541
SEP (C)	26.940	22.920	20.200	18.630	16.980	16.410	28.790	0 25.680	24.980	23.540	22.000	20.780
Slope	0.605	0.623	0.577	0.560	0.524	0.521	0.491	0.518	0.441	0.346	0.365	0.317
Intercept	47.100	43.900	48.900	52.900	58.300	57.800	60.100	0 58.500	70.800	84.600	82.700	89 600
A.S.D.	29.810	27.480	27.550	27.790	28.720	28.670	32.720	0 32.400	33.420	34.370	34.070	34 380
Blas - Bias CL	-14.197	-12.076	-10.649	-9.816	-8.945	-8.649	-15.175	5 -13.541	-13.162	-12.408	-11.596	.10.951
	Хөз	Yes	Yes	Yes	Yes	Yes	Κ θ3	Yes	Yes	Yes	Yes	Yes

Table 4b. (cont'd)

T	6 terms	1.87	0.535	0.202	1516	0 222	0.006	0.120	0.260	0.260	0.063	3.510	0 230	0.140	Yes			6 terms	3.72	0.924	1.586	1.516	1.782	0.869	0.950	0.260	2.060	0.885	6.080	1.940	0 690
	5 terms 6		0.520										l					5 lerms 6	6.03	0.919		1.565		0.876	0.980					1.884	
n 2,5,5	1		0.445 0						0.283 0			3.490 3					n 2,5,5	·	7.34	0 606:0		1.774	1.884	0.893 0	1.040 0	0.283 0	2.250 2	0.880	6.430 7	1.750	0.757 0
Step-up Regression 2,5,	ms 4 te																Step-up Regression 2,5,5	ms 4 lo													
Step-up			3 0.327	5 0.243			0.038		3 0.312	0.320	5 0.198	3.010	3 0.230		Yes		Step-ur		5 8.41	3 0.897	1.840	1.792	1.972	0.884	1.100	3 0.312	2.390	0.889	0 5.850	1.825	2 0.788
	2 terms	4.23	0.258	0.255	1.928	0.268	0.064	0.150	0.328	0.330	0.295	2.640	0.233	-0.178	Yes			2 terms	12.35	0.826	2.394	1.928	2.457	0.740	1.440	0.328	3.110	1.050	-3.300	1.825	1.112
	1 term	8.07	0.181	0.268	2.497	0.276	0.039	0.160	0.344	0.350	0.267	2.750	0.236	-0.184	Yes			1 term	80.75	0.679	3.248	2.497	3.328	0.755	1.950	0.344	4.220	1.090	.5.290	2.476	1.606
																ter in vivo															
	6 terms	0.00	0.530	0.203	1.546	0.226	0.033	0.120	0.261	0.260	0.156	3.160	0.239	0.141	, Kes	Digestibility of dry matter in vivo		6 terms	2.86	906.0	1.755	1.546	1.956	0.768	1.050	0.261	2.280	0.731	14.900	3.108	0.789
	5 terms	3.10	0.440	0.221	1.608	0.238	0.067	0.130	0.284	0.290	0.280	2.690	0.239	-0.154	Yes	Digestibility	•	5 terms	13.18	0.883	1.962	1.608	2.152	0.884	-180	0.284	2.550	0.777	11.900	2:734	0.896
p Regression 2,2,2	4 terms	2.65	0.370	0.235	1.743	0.248	0.104	0.140	0.302	0.310	0.341	2.470	0.239	-0.162	Yes		p Regression 2,2,2	4 terms	16.80	0.962	2.127	1.743	2.312	0.787	1.280	0.302	2.770	0.826	9.040	2.652	0.978
Step-up Regr	3 terms	3.22	0.334	0.241	1.867	0.252	0.087	0.140	0.310	0.310	0.345	2.460		-0.170	Yes		Step-up Regr	3 terms	8.71	0.830	2.365	1.867	2.557	0.664	1.420	0.310	3.070	0.792	-1000	2.584	1.110
- 1	2 terms	6.24	0.285	0.250	2.035	0.259	0.089	0.150	0.321	0.330	0.394	2.270	0.232	-0.171	Yes			2 terms	5.79	0.714	.3.069	2.035	3.250	0.712	1.840	0.321	3.990	0.805	10.300	2.877	1.519
	1 term	7.28	0.164	0.270	2.420	0.277	0.067	0.160	0.347	0.350	0.367	2.380	0.235	-0.187	Y 88			1 lerm	72.42	0.616	3.555	2.420	3.666	0.785	2.130	0.347	4.620	1.050	-2.180	2.484	1.783
1		Lowest partial F-ratio												llas CL	Blas CL7		•		Lowest partial F-ratio												Bias - Blas CL
		Lowest	, E	SEC	SEC CL	SEVICI		Blas	Bias CL	SEP (C)	Slope	Intercept	R.S.D.	Blasi - Blas Cl	Blas < Blas CL?			-	Lowest		SEC	SEC CL	SEVIC		Blas	Bias CL	SEP (C)	Slope	Intercep	R.S.D.	Bias - Blas Cl

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1 term 2 terms 3 terms 4 term 2 terms 3 terms 4 term 2 terms 3 terms 4 terms 3 terms 4						Digostibilis	roldryma	Digostibility of dry matter in vilvo						
Herm 2 learne 3 learne 5			5)	lep-up Reg	18sion 2,2,2					S	tep-up Regr	ession 2.5.]	
12.30 27.30 27.3 27.3 27.4 27.50		1 term	2 terms		4 terms	5 terms	6 terms	7	1 term		3 terms	4 terms		6 terms
0.0622 0.733 0.788 0.9853 0.915 0.015 0.715 0.784 0.783 0.784 0.784 0.783 0.784 0.784 0.783 0.784 0.784 0.783 0.784 0.784 0.785 1.784 1.286 1.787 1.286 2.487 1.782 1.784 1.286 1.787 1.286 2.487 1.286 1.786 1.787 1.286 2.487 1.286 1.786 1.787 1.480 1.686 1.787 1.286 1.787 1.286 1.686 1.687 1.487 1.480 1.687 1.480 1.686 1.687 1.480 1.686 1.687 1.480 1.686 <	Lowest partial F-ratio	73.30	5.73	8.71	17.00	13.23	2.99		81.21	12.38	8.48	7.23	6.07	3.72
311 3 544 5 2251 2 610 2 1777 2 2658 3 265 2 683 2 616 2 4077	R²	0.692	0.733	0.788	0.863	0.905	0.915		0.715	0.791	0.833	0.863	0.884	0 894
1,420 2,035 1,667 1,743 1,608 1,546 2,487 1,928 1,792 1,774 1,565 1,670 1,71	SEC	3.913	3.645	2.251	2.610	2.177	2.058		3.768	3.222	2.883	2.616	2.407	2 294
1,000 3,100 3,411 2,781 2,224 2,203 3,955 3,950 3,953 2,809 2,615 3,950 3,95	SEC CL	2.420	2.035	1.867	1.743	1.608	1.546		2.497	1.928	1.792	1.774	1.565	1.516
1,000 1,00	SEV(C)	4.020	3.186	3.411	2.781	2.324	2.203		3.855	3.360	3.063	2.809	2.615	2.490
Carrollo Carrollo	,	0.731	0.694	0.687	0.644	0.685	0.671		0.735	0.856	0.845	0.849	0.801	0 800
Lange Lang	Bias	2.350	2.190	1.950	1.570	1.310	1.230		2.260	1.930	1.730	1.570	1.440	1.380
S. 1090 A.740 A.230 2.830 2.860 A.900 A.190 3.750 3.7400 3.130 S. 1094 O.886 O.886 O.886 O.880 O.880	Slas CL	5.029	4.684		3.354	2.798	2.645		4.842	4.141	3.705	3.362	3.093	2.948
Digition Digition	SEP (C)	5.090	4.740		3.390	2.830	2.680		4.900	4.190	3.750	3.400	3.130	2.980
Dig	Slope	0.946	0.868		0.877	0.860	0.830		1.080	0.994	1.020	0.976	0.975	0.914
1,565 3,601 3,842 3,882 4,143 3,895 3,576 2,587 2,733 2,694 3,097 2,679 2,494 -0,943 -1,784 -1,489 -1,415 -2,582 -2,211 -1,975 -1,792 -1,653 -1,65	ntercept	5.000 2.000	5.890		6.140	7.240	9.150		-4.700	-0.410	.1.970	0.240	0.240	4.040
Class CL 765 2.494 -0.943 -1.784 -1.416 -1.415 -2.582 -2.211 -1.975 -1.792 -1.653 K Blas CL/F Yes	J.S.D.	3.565	3.601	3.842	3.682	4.143	3.895		3.576	2.637	2.733	2.694	3.097	3,103
C Blas CLT Yes	Blas - Blas CL	-2.679	-2.494	-0.943	-1.784	-1.488	-1,415	-	-2.582	-2.211	-1.975	-1.792	-1.653	-1.568
Siep-up Regression 2,10,5 Siep-up Regression 2,10,5 Siep-up Regression 2,10,6 Siep-up Regression 2,10,10 Siep-up Regression 2,10,10,10 Siep-up Regression 2,10,10 Siep-up Regression 2	Blas < Blas CL7	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Siap-up Regression 2,105 Siap-up Regression 2,101 Siap-up Regression							rodulrad	o ottoor						
1 letrm 2 letrms 5 letrms 6 letrms 6 letrms 1 letrm 2 letrms 3 letrms 4 letrms 5 letrms 6 letrms 1 letrm 2 letrms 3 letrms 4 letrms 5 letrms 5 letrms 5 letrms 5 letrms 4 letrms 5 letrms 4 letrms 5 letrms 4 letrms <t< td=""><td></td><td></td><td></td><td>tep-up Regr</td><td>ession 2,10,</td><td>2</td><td></td><td></td><td></td><td>Ste</td><td>p-up Regre</td><td>sslon 2, 10, 1</td><td>0</td><td></td></t<>				tep-up Regr	ession 2,10,	2				Ste	p-up Regre	sslon 2, 10, 1	0	
11 partial F-ratio 25.11 14.92 5.87 4.42 7.61 1.89 23.54 15.23 4.01 4.30 4.35 10 partial F-ratio 0.430 0.606 0.661 0.697 0.755 0.763 0.413 0.599 0.641 0.678 0.721 1.942 1.613 1.496 1.415 1.273 1.252 1.970 1.631 1.460 1.358 1. 2.510 2.084 1.933 1.829 1.645 1.618 2.546 2.108 1.991 1.460 1.358 1. 2.510 2.084 1.933 1.625 1.649 1.639 1.618 2.546 2.108 1.991 1.494 1. 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.619 1.494 1. 0.273 0.456 0.476 0.498 0.291 0.451 0.517 1. 1.100 0.950 0.850 0.750		1 lerm	2 terms		4 terms	5 terms	6 terms		1 term	2 terms	3 terms	4 terms	5 terms	6 terms
0.430 0.606 0.661 0.697 0.755 0.763 0.413 0.598 0.641 0.678 0.721 1.342 1.613 1.496 1.415 1.273 1.252 1.970 1.631 1.541 1.460 1.358 1. 2.510 2.084 1.933 1.829 1.615 1.618 2.546 2.108 1.991 1.887 1.755 1. 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.612 1.569 1.494 1. 2.020 1.674 1.611 1.403 1.392 2.047 1.689 1.612 1.569 1.494 1. 2.020 1.674 1.630 0.760 0.750 1.180 0.980 0.880 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 <td>Lowest partial F-ratio</td> <td></td> <td>14.92</td> <td></td> <td>4.42</td> <td>7.61</td> <td>1.89</td> <td></td> <td>23.54</td> <td>15.23</td> <td>4.01</td> <td>4.30</td> <td>4.35</td> <td>4.66</td>	Lowest partial F-ratio		14.92		4.42	7.61	1.89		23.54	15.23	4.01	4.30	4.35	4.66
1.942 1.613 1.496 1.415 1.273 1.252 1.970 1.631 1.541 1.460 1.358 1. 2.510 2.084 1.933 1.645 1.618 2.546 2.108 1.991 1.887 1.755 1. 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.612 1.569 1.494 1. 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.612 1.569 1.494 0.273 0.396 0.456 0.476 0.498 0.291 0.333 0.401 0.454 0.517 1. 1.170 0.970 0.960 0.760 0.750 1.180 0.980 0.980 0.810 1. 2.520 2.100 1.923 1.840 1.630 1.630 2.120 2.096 1.960 1.745 1. 2.520 2.103 1.630 1.630 0.610 <th< td=""><td>, L</td><td>0.430</td><td>909.0</td><td>0.661</td><td>0.697</td><td>0.755</td><td>0.763</td><td></td><td>0.413</td><td>0.598</td><td>0.641</td><td>0.678</td><td>0.721</td><td>0.755</td></th<>	, L	0.430	909.0	0.661	0.697	0.755	0.763		0.413	0.598	0.641	0.678	0.721	0.755
1. 2.510 2.084 1.933 1.829 1.645 1.618 2.546 2.108 1.991 1.887 1.755 1) 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.612 1.599 1.494 1 0.273 0.398 0.456 0.473 0.476 0.498 0.291 0.333 0.401 0.459 1.597 1 1.70 0.970 0.900 0.850 0.760 0.750 1.180 0.291 0.333 0.401 0.454 0.517 1 2.496 2.073 1.923 1.818 1.656 1.609 2.532 2.096 1.980 1.760 1 2.520 2.100 1.950 1.840 1.650 1.630 2.560 2.120 2.000 1.900 1.760 1 2.520 2.100 1.630 0.616 0.616 0.737 0.581 0.639 0.653 0.715 1	SEC	1.942	1.613	1.496	1.415	1.273	1.252		1.970	1.631	1.541	1.460	1.358	1.274
1) 2.020 1.674 1.611 1.541 1.403 1.392 2.047 1.689 1.612 1.569 1.494 0.273 0.273 0.396 0.475 0.496 0.291 0.333 0.401 0.454 0.517 L 2.496 2.073 0.900 0.850 0.760 0.750 1.180 0.980 0.890 0.810 L 2.496 2.073 1.923 1.818 1.636 1.609 2.532 2.096 1.880 1.745 J 2.520 2.100 1.950 1.818 1.650 1.639 2.550 2.100 1.900 1.745 J 2.520 2.100 1.950 1.840 1.650 1.630 2.560 2.120 2.000 1.900 1.765 J 2.520 2.100 1.650 1.630 2.140 3.720 5.850 5.040 5.040 4.130 L 2.170 2.193 2.343 2.367 2.524 <td>SEC CL</td> <td>2.510</td> <td>2.084</td> <td>1.933</td> <td>1.829</td> <td>1.645</td> <td>1.618</td> <td></td> <td>2.546</td> <td>2.108</td> <td>1.991</td> <td>1.887</td> <td>1.755</td> <td>1.646</td>	SEC CL	2.510	2.084	1.933	1.829	1.645	1.618		2.546	2.108	1.991	1.887	1.755	1.646
0.273 0.398 0.456 0.473 0.476 0.498 0.291 0.333 0.401 0.454 0.517 L 2.496 2.073 1.923 1.816 0.750 1.180 0.980 0.920 0.880 0.810 L 2.496 2.073 1.923 1.818 1.636 1.609 2.532 2.096 1.880 1.745 J 2.520 2.100 1.950 1.840 1.650 1.630 2.560 2.120 2.000 1.900 1.760 pt 0.706 0.723 0.717 0.707 0.610 0.616 0.737 0.581 0.639 0.653 0.715 pt 4.150 3.950 4.320 4.260 5.620 5.440 3.720 5.850 5.040 5.040 5.040 4.130 Blas CL 1.326 1.023 0.968 0.876 0.859 1.135 1.116 1.060 0.996 0.936 0.9859 1.335 1.116	SEV(C)	2.020	1.674	1.611	1.541	1.403	1.392		2.047	1.689	1.612	1.569	1.494	1.411
1,170 0,970 0,900 0,850 0,750 1,180 0,980 0,920 0,880 0,810 2,496 2,073 1,923 1,818 1,636 1,609 2,532 2,096 1,880 1,876 1,745 2,520 2,100 1,950 1,840 1,650 1,630 2,560 2,120 2,000 1,900 1,760 0,706 0,723 0,717 0,707 0,610 0,616 0,737 0,581 0,639 0,653 0,715 0,706 0,723 0,717 0,707 0,610 0,616 0,737 0,581 0,639 0,653 0,715 0,706 0,732 2,343 2,347 2,524 2,375 2,179 1,607 1,666 1,644 1,889 1,326 1,103 1,023 0,968 0,876 0,859 1,352 1,116 1,060 0,996 0,935 1,326 1,103 1,023 7,98		0.273	0.398	0.456	0.473	0.476	0.498		0.291	0.333	0.401	0.454	0.517	0.541
L 2.496 2.073 1.923 1.616 1.636 1.609 2.532 2.096 1.880 1.876 1.745 2) 2.520 2.100 1.950 1.840 1.650 1.630 2.560 2.120 2.000 1.900 1.760 pt 0.706 0.723 0.717 0.707 0.610 0.616 0.737 0.581 0.639 0.653 0.715 pt 4.150 3.950 4.320 4.260 5.620 5.440 3.720 5.850 5.040 5.040 4.130 Blas CL 1.326 -1.103 -1.023 -0.968 -0.875 -1.352 -1.116 -1.060 -0.996 -0.975 Blas CL Yes Yes Yes Yes Yes Yes Yes	Sias	1.170	0.970	0.90	0.850	0.760	0.750		1.180	0.980	0.920	0.880	0.810	0.760
2) 2.520 2.100 1.950 1.840 1.650 1.630 2.560 2.120 2.000 1.900 1.760 pt 0.706 0.723 0.717 0.707 0.610 0.616 0.737 0.581 0.639 0.653 0.715 pt 4.150 3.950 4.320 4.260 5.620 5.440 3.720 5.850 5.040 5.040 4.130 Blas CL 2.170 2.193 2.347 2.524 2.375 2.179 1.607 1.666 1.644 1.889 Blas CL 1.326 -1.103 -1.023 -0.968 -0.876 -0.859 -1.352 -1.116 -1.060 -0.996 -0.935 Blas CL7 Yes Yes Yes Yes Yes Yes Yes	Blas CL	2.496	2.073	1.923	1.818	1.636	1.609		2.532	2.096	1.980	1.876	1,745	1.637
pt 4.150 3.950 4.320 4.260 5.620 5.440 3.720 5.850 5.040 5.040 4.130 Blas CL 1.326 -1.103 -1.023 -0.968 -0.876 -0.859 -1.352 -1.116 -1.060 -0.996 -0.959 -0.959 -0.956 -0.959 -0.959 -0.956 -0.959 -0.956 -0.959 -0.956 -0.956 -0.959 -0.956 -0.	SEP (C)	2.520	2.100		1.840	1.650	1.630		2.560	2.120	2.000	1.900	1.760	1.660
pt 4.150 3.950 4.320 4.260 5.620 5.440 3.720 5.850 5.040 5.040 4.130 2.170 2.170 2.193 2.343 2.357 2.524 2.375 2.179 1.607 1.666 1.644 1.889 Blas CL -1.326 -1.103 -1.023 -0.968 -0.876 -0.859 -1.352 -1.116 -1.060 -0.996 -0.935 Blas CL7 Yes Yes Yes Yes Yes Yes Yes	Slope	0.706	0.723		0.707	0.610	0.616		0.737	0.581	0.639	0.653	0.715	0.709
2.170 2.193 2.343 2.367 2.524 2.375 2.179 1.607 1.666 1.644 1.889 Blas CL 1.326 1.103 1.023 0.968 0.876 0.859 1.352 1.116 1.060 0.996 0.935 Blas CL? Yes	ntercept	4.150	3.950	4.320	4.260	5.620	5.440		3.720	5.850	5.040	5.040	4.130	4.160
-1.326 -1.103 -1.023 -0.968 -0.876 -0.859 -1.352 -1.116 -1.060 -0.996 -0.935 Yes	1.S.D.	2.170	2.193	2.343	2.367	2.524	2.375		2.179	1.607	1.666	1.644	1.889	1.893
Yes	Bias - Blas CL	-1.326	103	.1.023	.0.968	-0.876	.0.859		-1.352	-1.116	-1.060	-0.996	-0.935	-0.877
	Bias < Blas CL7	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes

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Table

					Energy req	Energy required to comminute	ımlnute							
		St	Step-up Regre	p Regression 2,10,5					Step	-up Regres	Step-up Regression 2,10,10	0		
	1 term	2 terms	3 terms	4 lerms	5 terms	6 terms	1 term		2 terms	3 terms	4 terms	5 terms	6 terms	
Lowest partial F-ratio	76.72	5.31	2.76	2.18	1.68	1.01	74.85		5.39	2.13	2.96	4.38	1.49	
H ²	0.703	0.739	0.754	0.763	0.772	0.800	0.698		0.735	0.745	0.761	0.787	0.791	
SEC	21.158	19.825	19.267	18.887	18.518	17.344	21.345		19.977	19.611	18.982	17.929	17.768	
SEC CL	2.510	2.084	1.933	1.829	1.645	1.618	2.546		2.108	1.991	1.887	1.755	1.646	
SEVIC	21.803	20.707	20.279	19.690	19.499	18.691	22.033		20.904	20.985	19.911	18.777	18.634	
3	0.460	0.468	0.414	0.394	0.330	0.215	0.434		0.450	0.408	0.397	0.357	0.387	
Rias	12.690	11.890	11.560	11.330	11.110	10.410	12.810		11.990	11.700	11.390	10.760	10.660	
Rias CL	27.191	25.478	24.761	24.273	23.799	22.290	27.432		25.674	25.203	24.395	23.042	22.835	
SEP (C)	27.510	25.770	25.050	24.550	24.070	22.550	27.750		25.970	25.490	24.680	23.310	23.100	
Slone	0.793	0.737	0.688	0.649	0.598	0.468	0.776		0.729	0.694	0.645	0.622	0.633	
Intercept	18.300	24.500	31.800	39.600	48.100	67.100	20.200		25.600	30.800	39.000	43.600	42.200	
A.S.D.	26.610	26.420	27.720	28.170	29.640	32.080	27.230		26.850	27.860	28.100	29.030	28.350	
IRiasl - Blas Cl	-14.501	-13.588	-13.201	-12.943	-12.689	-11.880	.14.622		-13.684	-13.503	-13.005	-12.282	-12.175	
IRiasi < Rias CL?	χθ8	Yes	Yes	Yes	Yes	Yes	Yes	98	Yes	Yes	Yes	Yes	Yes	
					Energy re	Energy required to compress	mpress							
_		S	Step-up Regr	p Regression 2,10,5					Ste	p-up Regre	Step-up Regression 2,10,10	10		
	1 term	2 terms	3 terms	4 terms	5 terms	6 terms	1 16	1 term 2	2 terms	3 terms	4 terms	5 terms	6 terms	_
Lowest partial F-ratio	8.16	2.24	8.06	4.06	1.97	4.98	6.50	20	4.94	4.91	1.75	3.54	3.83	
R ²	0.183	0.214	0.364	0.457	0.532	0.592	0.147		0.243	0.397	0.412	0.461	0.512	
SEC	0.267	، 0.262	0.236	0.218	0.202	0.189	0.273		0.257	0.230	0.227	0.217	0.207	,
SEC CL	2.510	2.084	1.933	1.829	1.645	1.618	2.5	2.546	2.108	1.991	1.887	1.755	1.646	
SFV(C)	0.278	0.275	0.252	0.235	0.218	0.210	0.2	0.283	0.273	0.250	0.250	0.247	0.235	
2	0.010	0.028	0.052	0.076	0.086	0.053	0.0	900.0	0.057	0.045	0.052	0.035	0.029	
Rias	0.160	0.160	0.140	0.130	0.120	0.110	0.1	0.160	0.150	0.140	0.140	0.130	0.120	
Bias CL	0.343	0.337	0.303	0.280	0.260	0.243	0.0	0.351	0.330	0.296	0.292	0.279	0.266	
SEP (C)	0.350	0.340	0.310	0.280	0.260	0.250	0.	0.360	0.330	0.300	0.290	0.280	0.270	-
Slope	0.127	0.212	0.239	0.252	0.218	0.142	Ö	0.102	0.294	0.216	0.212	0.149	0.149	
Intercept	3.270	2.960	2.850	2.800	2.930	3.210	3.0	3.360	2.640	2.940	2.950	3.180	3.190	
R.S.D.	0.234	0.233	0.235	0.236	1.942	1.495		1.736	1.938	1.980	2.030	2.179	2.183	_
Blas - Blas CL	.0.183	.0.177	-0.163	-0.150	-0.140	.0.133		0.191	-0.180	-0.156	-0.152	-0.149	.0.146	
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	Yes	>	Yes	Yes	Yes	Yes	Yes	Yes	_
				-										

Table 4b. (cont'd)

					Digeotibilit	y of dry ma	Digeotibility of dry matter in vivo	一次			2 2 2 2	
		Sol	Step-up Reg	ip Regression 2,10	5				In Ban	Sten-tip Begression 2 10 10	Ç	
	1 term	2 terms	3 terms	4 terms	5 terms	6 terms	1 term	2 terms	3 larms	4 locare	0,1	
Lowest partial F-ratio	91.59	9.46	9.77	7.10	2.58	4.12	93.60		18.07	4 26	Silling	o lerms
P.	0.700	0.867	0.902	0.916	0.927	0.935	0.675		age C	1.30	80.00	4.94
SEC	3.139	2.095	1.794	1.660	1.545	1.457	3271		1 828	1000	0.922	0.927
SEC CL	2.510	2.084	1.933	1.829	1.645	1.618	2 5.4E		0707	1.096	1.59B	1.546
SEV(C)	3.332	2.282	1.997	1.830	1.694	1.607	1 25.7		S .	1.887	1.755	1.646
ا کم	777.0	0.856	0.888	0.871	0.887	0.881	808.0		2.016	1.905	1.840	1.787
Blas	1.880	1.260	1.080	1.000	0.930	0.870	1 960		0.803	0.836	0.877	0.892
Blas CL	0.343	0.337	0.303	0.280	0.250	0 243	1000		3	1.020	0.960	0.930
SEP (C)	4.080	2.720	2.330	2.160	2.010	- Bay	0.331		0.296	0.292	0.279	0.266
Slape	0.892	0.880	0.924	0.870	0.851	0 827	067.4		2.380	2.210	2.080	2.010
Intercept	7.380	6.750	3.930	6.850	8.320	208	1.130		0.812	0.829	0.840	0.865
A.S.D.	2.531	2.034		1 927	4 799	1 848	0.490		9.960	9.030	8.710	7.270
(Biasl - Blas CL	1.537	0.923	0.777	0.720	0.670	0.63.0	27.75		2.344	2.172	1.876	1.761
Risel / Rise Ct 2	SZ.	N N				0.067	1.603	1.150	0.804	0.728	0.681	0.664
	2	2	2		No	No.	No No	Š	ટ	Ş	£	2
		Ú	Stop up Bozz	Total control of	DIAGENTALIAN OF GRANDERS IN MITTO	OI OUT WE	TOT IN WITTO					
	tom	2 10,000	להיים להיים	4 100					tep-up Regre	Step-up Regression 2,10,10	01	
citer 3 leiben from 1	111111	SILIDI 7	2100	4 lerms	S terms	6 lerms	1 term	2 terms	3 terms	4 terms	5 lerms	6 lerms
בייים: המוומן ימווס	31.16	0.02	10.01	4.40	4.61	5.01	92.14	9.60	9.70	10.55	2.67	7.7.5
1000	2 550	0.784	0.856	0.871	0.886	0.901	0.740	0.797	0.842	0.881	0.888	000
SECICI	2.300	20.50	4.000	2.532	2.384	2.224	3.596	3.182	2.802	2.430	2.361	2 2 2 5
35000	010.5	2.084	1.933	1.829	1.645	1.618	2.546	2.108	1.991	1.887	1755	1 546
SEVIC)	3.633	3.371	2.785	2.667	2.563	2.364	3.655	3.280	2.892	2.618	2.525	2.416
- 6:0	0.020	0.810	0.813	0.802	0.819	0.851	0.823	0.807	0.810	0.844	0.818	0.823
Dida	20.140	0/6:1	019.1	1.520	1.430	1.330	2.160	1.910	1.680	1.460	1 420	1 340
DIBS OF	4.383	4.219	3.444	3.254	3.064	2.858	4.621	4.089	3.601	3.123	3 034	2 872
SEP (C)	4.640	4.270	3.480	3.290	3.100	2.890	4.680	4.140	3.640	3.160	3 070	2002
Siope	0.300	0.971	0.906	0.862	0.867	0.864	0.937	0.927	0.882	0.935	0 881	0.910
Intercept	2.120	1.280	4.530	7.230	7.380	7.610	3.490	3.660	5.790	3.260	140	0.04
H.S.D.	2.978	3.002	3.088	2.952	2.681	2.922	3.023	2.742	2.959	2.84B	0.231	0.000
Biasi - Bias CL	-2.445	-2.249		-1.734	-1.634	.1.528	-2.461	-2.179	-1.921	.1663	1614	653
Blas < Bias CL7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	× ×	202.	+101+	1.532
_									20	783	Yes	Yes

Table 4c. Calibration and validation statistics (multivariate regressions)

		regres		A Seesand - Labour		i kaja en h
11 分別或額銀 音		nergy requ			MP	
1		CR	PL		2,5,5	2.10,10
	2,5,5	2,10,10	2,5.5	2.10,10		
R ²	0.847	0.752	0.639	0.601	0.601	0.582
SEC	1.036	1.290	1.545	1.624	1.550	1.586
SEC CL	1.199	1.493	1.788	1.879	1.793	1.835
SECV	1.750	1.592	1.788	1.933	1.600	1.583
r ²	0.5441	0.4876	0.4938	0.4157	0.3080	0.3563
Bias	0.620	0.770	0.930	0.970	0.930	0.950
Bias CL	1.331	1.658	1.986	2.087	1.992	2.038
SEP (C)	1.350	1.680	2.010	2.110	2.020	2.060
Slope	0.6540	0.6850	0.7390	0.6270	0.5220	0.6000
intercept	5.2900	4.8100	3.7500	5.4500	7.3100	6.0200
R.S.D.	1.671	1.776	1.761	1.892	2.065	1.992
Bias - Bias CL	-0.711	-0.888	-1.056	-1.117	-1.062	-1.088
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	Yes
4, 18, 20, 20, 20, 20, 20, 20, 20, 20, 20, 20	Ene	rgy require	d to commi	nute	an Seesan	
· ·	PC	CR		<u>.s</u>	MP	
	2,5,5	2,10,10	2,5,5	2,10,10	2,5.5	2,10,10
R ²	0.584	0.574	0.605	0.595	0.556	0.558
SEC	23.378	23.682	22.788	23.075	24.164	24.101
SEC CL	27.048	27.400	26.366	26.698	27.958	27.885
SECV	26.030	26.121	25.548	25.683	26.409	26.252
12	0.349	0.337	0.332	0.325	0.33	0.328
Bias	14.030	14.210	13.670	13.840	14.500	14.460
Bias CL	30.044	30.435	29.286	29.655	31.055	30.974
SEP (C)	30.390	30.790	29.620	30.000	31.410	31:330
Slope	0.649	0.636	0.644	0.632	0.657	0.638
Intercept	37.3	39.2	38.1	39.7	36.6	39.1
R.S.D.	28.246	28.676	28.714	28.884	28.651	28.900
Bias - Bias CL	-16.014	-16.225	-15.616	-15.815	-16.555	-16.514
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	Yes
Here was a firm to the first that the	En	ergy require	d to compr	ess		na Salandara tukin e
	P	CR		<u>_S</u>		rLS
_	2.5.5	2,10,10	2.5.5	2,10,10	2.5.5	2,10,10
R ²	0.251	0.160	0.231	0.208	0.038	0.040
SEC	0.225	0.241	0.265	0.269	0.260	0.260
SEC CL	0.260	0.279	0.307	0.311	0.301	0.301
SECV	0.299	0.277	0.301	0.307	0.301	0.299
12	0.0220	0.0120	0.0130	0.0090	0.0060	0.0080
Bias	0.140	0.140	0.160	0.160	0.160	0.160
Bias CL	0.289	0.310	0.341	0.346	0.334	0.334
SEP (C)	0.290	0.310	0.340	0.350	0.340	0.340
Slope	0.2290	0.2270	0.1530	0.1330	0.2290	0.2590
intercept	2.8900	2.9000	3.1700	3.2500	2.8900	2.7700
R.S.D.	0.235	0.236	0.236	0.237	0.237	0.237
Bias - Bias CL	-0.149	-0.170	-0.181	-0.186	-0.174	-0.174
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	Yes
10.00 10.00						

Table 4c (cont'd) Calibration and validation statistics (multivariate regressions)

	(iiii	litivariate	e regres	sions)		
	Dig	estibility of	dry matter	in vivo	· Haran Art	1.
		PCR		PLS		MPLS
R ²	2.5,5	2,10,10	2,5.5	2,10,10	2,5.5	2,10,10
1	0.909	0.900	0.958	0.937	0.571	0.892
SEC	1.638	1.711	1.109	1.356	3.756	1.911
SEC CL	1.895	1.980	1.283	1.569	4.346	2.211
SECV	2.159	2.075	1.957	1.776	3.797	2.180
r ²	0.9022	0.8865	0.8447	0.8457	0.6963	0.8671
Bias	0.980	1.030	0.670	0.810	2.250	1.150
Bias CL	2.105	2.199	1.425	1.743	4.827	2.456
SEP (C)	2.130	2.220	1.440	1.760	4.880	2.43 0 2.480
Slope	0.848	0.807	0.839	0.822	0.981	
Intercept	8.77	11.1	8.65	9.41	1.99	0.745
R.S.D.	1.704:	1.834	2.143	2.139	2.914	14.6 1.984
Bias - Bias CL	-1.125	-1.169	-0.755	-0.933	-2.577	
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	-1.306
	Dige	stibility of d		z idkno	1 63	Yes
	P	CR		LS	h.a.	PLS
·	2,5,5	2.10,10	2,5,5	2,10,10	2.5.5	
R ²	0.820	0.790	0.780	0.760	0.420	2,10,10
SEC	2.880	3.100	3.330	3.470	5.380	0.490
SEC CL	3.332	3.587	3.853	4.015	6.225	4.850
SECV	3.170	3.560	3.830	3.900	5. 69 0	5.611
²	0.B120	0.7730	0.8530	0.8040	0.6910	4.780 0.6690
Bias	1.730	1.860	2.000	2.080	3.230	2.910
Bias CL	3.701	3.984	4.280	4.459	6.914	6.233
SEP (C)	3.740	4.030	4.330	4.510	6.990	6.310
Slope	0.9180	0.9840	0.9530	0.6120	1.1200	0.8650
Intercept	3.4700	-0.3600	2.3100	4.6300	-7.5100	6.1800
R.S.D.	3.053	3.363	2.836	3.089	3.911	4.002
Bias - Bias CL	-1.971	-2.124	-2.280	-2.379	-3.684	-3.323
Bias < Bias CL?	Yes	Yes	Yes	Yes	Yes	-3.323 Yes
						169

Table 5. Standard error of laboratory determination (SEL)

	Energy required to shear (kJ/m²)	Energy required to comminute (kJ/kg DM)	Energy required to compress (kJ/kg DM)	Digestibility of dry matter in vivo (%)	Digestibility of dry matter in vitro (%)
Mean SEL (n=65)	0.796	5.830	0.078	not available	0.314
Median SEL	0.788	5.492	0.085	not available	0.270
Maximum SEL	2.044	13.098	0.211	not available	1.126
Minimum SEL	0.114	0.760	0.019	not available	0.005
SEL CL (using mean SEL)	1.035	7.319	0.101	not available	0.408
SEL CL (using median SEL)	1.024	7.140	0.111	not available	0.351

Table 6a. Components of possible prediction equations from stepwise and step-up regression analyses.

	Coofficient	Wavelongth	Conficient	Wavolangth
		Encirgy root	dred to shear	
Regression energels Mathematical treatment	Stcp 2.2.2 (6	erico I transs)	Stc; 2,5,5 (2	o-mo
ModRieden destroit		(43,112)	43,5 (2	(terns)
	19.95 2452.05	2048	28.09 1035.77	
	-Q335.61	1528	700.12	2048 1958
	3823.49	1458		16.60
	-\$319.88 5149.38	1718 1829		
,	10238.48	1169		
				
Regrossion enalysis	Sicp		ad to compross	
Mathametical troopsant	2,10,10 (Stop 2,10,5 (3	
	-0.71		2.49	
1	-28.02	2278	-31.05	1728
1	112.57	1588	-108.89	1548
	-79.48 -911.04	1726 1238	-405.95	1268
			d to comminute	
Regression analysis Mathematical treatment	Stop: 2,10,5 (4		Stop	
	2,10,3 (4	CHAS	2,10,5 (1	i uam)
	231.42		-69.08	
	-3003.37 4220.19	2128 2408	-1521:33	2238
	-<955.12	2018		
	18224.74	1138		
·				
		Digostibility of d		
Regression analysis Mathematical treatment	Stop: 2,5,5 (6		Stop 2,10,5 (3	
	46.62		49.16	
·	-387.08	1918	≪9.16 -612.43	1698
j	-8729.69	1238	252.82	1418
į	8162.72	1158	-943.77	1618
	1249.01 519.48	1658 1998		•
	-161.84	2248	•	•
		Digastibility of d	Or matter in with	: •
Regression analysis	Stepe	×i30	Step	-up
Mathematical treatment	2,5,5 (5	torms)	2,10,10 (4	
	83.43		54.29	. = -
ļ	-556.01	1918 1908	-1171.70	1698
	981,30 -2186,89	1698	311.12 -2857.89	1418 1818
į i	2003.05	2158	-2319.81	1228
	-1491,99	1748		

		Wavelength		1108	1118	1128	1138	1148	1158	1168	1178	1189	1198	1208	1218	128	0071	1258	1268	1278	1288	1298	1308	1318	1328	1338	348	1358	368	1378	1388	1398	_
o comminute	PLS (2,6,6)		.16.44	91.01	7.19	-5.63	-0.13	5.58	-8.55	4.72	13.27	17.36	7 +.0	-13.98	-23.8	-15.15	79.7	-0.82	-3.84		4.93	7.12	10.4	16.14	23.58	27.65	10.27	-24.35	7:09	222	67.91	115.99	174.79
Energy required to comminute	2,6,6)	Wavelength		1108	1118	1128	1138	1148	1158	1168	1178	1188	1198	1208	1218		270	1258	1268	1278	1288	1298	1308	1318	1328	1338	348	1358	9961	1378	1388	1398	200
	PCR (2,6,6	Coefficient	-22.8	93.07	6.5	-7.27	-0.79	3.98	-10,39	89	13.75	19.07	90.5	6 .92	-20.83	a. /- c	97.5	-2.55	797	1,28	5.24	2.9	8.22	14.28	727	27.63	6.64	-28.23	8, g	31	67.77	125.67	100.24
nergy required to compress	PCR (2,6,6)	Wavelength		1108	1118	1128	1138	1148	1158	1168	1178	1188	1.98	- 50g	1218	1278	0071	128	1268	1278	1288	1298	1308	1318	1328	88. 13.	2	138	88 88 88	1378	1388	338	2
Energy require	PCR	Coefficient	3.35	0.17	0.02	000	0.04	0.01	-0.01		6.03	90:04	0	0.03	8	\$ \$ \$	0.0		0.0	0	0.01	0.02	0.03	200	90.0	0.07	0.03	80.0	0.15	00	0.16	603	540
Energy required to shear	PCR (2,5,5)	Wavelength		1108	1118	1128	1138	1148	85.	1168	1178	1188	1198	1208	1218	1228	8671	852	1268	1278	1288	1298	1308	1318	1328	1338	1348	1358	1368	1378	1388	1398	1408
inergy redu	PS.	Coefficient	333	181	1 78	9.5	780	1.15	585	0.13	0.64	0.0	49.0	-1.14	-1.71	-1.73	3. 3	7.0	9	-1.25	-0.25	0.2	1.0	99.0	1.25	S	2.34	-2.37	-10.62	-9.69	2. 86.	8.65	2 2

SUBSTITUTE SHEET (RULE 26)

	PLS (2,6,6)	Wavelength	1438	1448	1458	1468	1478	1484	- - -	503	1518	1528	1538	\$ 7	1558	895	1578	1588	1596	1608	1618	1628	959	8	889	9001	88	8 g	170	1718	1728	1738	1748	2 22	8 2 2	8/L/	022
1 to comminute	PLS	~ l	-137.82	-75.27	£7.38	₹ %	-59.84	-28.08	-3.2	3.33	28.01	48.03	33.02	0.48	-17.62	3.35	-15.39	40.21	32.77	-5.83	22.42	\$3.5 \$3.5	44.32	-2.24	8	38.22	60.49	42.6	27.79	-46.38	69.44	63.67	91.13	20.27	28 .58	-39.05	
Energy required to comminute	2,6,6)	uzbuelengan , 135	83	84	1458	488	1478	488	498		1518	PZCI.	25.5 25.5 25.5 25.5 25.5 25.5 25.5 25.5	2	558	258	1578	9961	908	2 E	1628	1636	1648	1658	668	1678	1688	1698	208	1718	1728	1738	2	1758	1768	1778	4057
 .	PCR (2,6,6)	145.28	- AR 7.4	27.5	5.5	25.5	4.0/- 6.0/-	£0.07-) .	28.80	20.00	2 2	8.6	7 6	A/117-	5 5	43.00	300	-7.28	17.4	8.8	49.47	53.35	3.16	-82.03	80.5		7 5	3 S	8 8	20.05	70.00	2 2	18.12	7: 5	3 5	11 61
Energy required to compress	Wavelength	1438	1448	1458	1468	1478	1488	464	98	1518	1528	623	15/48	855	258	1578	1588	1598	1603	1618	1628	859	960	83	929	868	3 2	502	1718	1728	17.38	1748	1758	3 5	173	1788	3
Energy require	Coefficient	-0.39	-0.21	0.13	-0.4	0.14	90.0	0.0	0.01	0.07	0.12	90.0	0	9	-0.0	9 00	90.0	-0.07	0.01	3 .8	25.0	2 -	<u>.</u>	2	700	0.15	90.0	80.0	90.0	0.13	0.15	0.19	90.0	0	0.11	600	• 1::
Energy required to ahear PCR (2.5.8)	A	1438	1448	£54	1468	1478	1488	1498	1508	1518	1528		5.48 84.01	1558	1588	1578	1588	288	1608	8191	8.8	979	1659	8991	1678	1888	1689	1708	1718	1728	1738	1748	1758	1768	1778	1788	
Energy required PCR (2,5,6	벌	10.01	3 9	2.03	-2.69	-8.0 5	-1.2	-2.08	-1.69	0.35	2.8	0.01	-1.83 	-3.7	99.0	- -	3.67	8. S.	8 6	2.03	188	16.23	10.67	6.52	-20,53	-6.15	7.4	4.78	-19.73	-5.98	19.24	6.42	-3.1	4.03	-1.47	4.0	

Components of possible prediction equations from multivariate regression analyses. Table 6b.

Energy red	Energy required to shear	Energy require	ergy required to compress		Energy required to comminute	1 to comminute	
	PCR (2,6,6)	PCR (2,6,6)	_	т.	PCR (2,6,6)	PLS (2,6,6)	_
Coefficient	Wavelength	Coefficient	Wavelength	Coefficient	Wavelength	Coefficient	Wavelength
2.78	1808	90.0	1808	20.97	1808	18.41	1808
-3.79	1818	0.01	1818	-8.58	1818	-5.17	1818
4.32	1828	20.02	1828	-30.81	1828	-28.5	1828
2.97	1838	50.05	1838	-17.29	1838	-17.64	1638
1 97	1848	0.03	848	17.65	1848	15.59	1848
.2 48	828	90:0	1658	28.08	1858	28.11	1858
84.	1868	0.08	1868	42.2	1868	40.48	1868
-10.22	1878	0.23	1878	115.52	1878	108.98	1878
3	1888	0.44	1888	219.15	1888	.208.1	1888
31.11	1898	0.2	1898	98.82	1898	89.42	1898
2.3	808	-0.35	1908	-179.9	1908	-157.11	1908
.25.69	1918	0.47	1918	-251.3	1918	.220.58	1918
-12.22	1928	0.34	1828	-171.83	1928	-172.09	1928
15.11	1938	-0.14	1938	85.33	1938	-71.27	1838
26.89	1948	-0.03	1948	-8.17	1948	-23.21	1948
27.72	1958	20.0	1958	-16.65	1958	-19.03	1858
6.83	1968	9.05	1988	12.02	1968	22.48	1968
-15,33	1978	0.23	1978	66.03	1978	96.98	1978
-9.25	1988	0.29	1988	85.84	1988	103.6	1968
3.33	1998	0.27	1998 8661	78.89	1898	59 .03	1998
1.28	2008	0.32	2008	97.63	2008	115.14	2008
20.22	2018	0.25	2018	104.79	2018	99.25	2018
18.34	2028	90'0	2028	42.08	2028	33.39	2028
8.58	2038	500	2038	23.98	802	=:=	2038
5.59	20 4 8	0.13	50 4 8	101.85	2048	77.38	2048
55	2028	0.21	2028	126.79	3058	109.6	2028
-18.75	2088	-0.2	5066	-75.99	2068	-71.48	2068
-18.33	2078	84.0	2078	-208.62	2078	-188.9	2078
-10.13	2068	86.0	2088	-151.16	2088	-143.85	2088
5.78	802	92.0	2038	-107.24	2038	-104.89	2038
4.44	2108	-0.28	2108	-108.08	2108	-107.49	2108
-6.28	2118	-0.23	2118	90.16	2118	·91.23	2118
4. 64.	2128	-0.23	2128	-97.55	2128	-93.37	2128
-16.58	2138	-0.2	2138	-101.35	2138	-85.08	2138
90.6	2148	0.0	2148	-13.78	2148	-0.31	2148
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2328 -0.47 2328 -167.65 2338 -0.2 2338 -167.65 2348 0.15 2348 62.44 2358 -0.07 2358 -23.09 2378 -0.05 2368 -23.09 2388 -0.05 2348 -3.15 2398 0.02 2398 98.53 2408 0.22 2408 130.67 2428 0.22 2428 120.05 2438 0.03 2448 67.27 2458 0.11 2448 65.83 2458 0.16 2458 65.83	2338 047 2318 207.81 2338 -0.47 2328 -167.85 2338 -150.99 2338 -0.15 2338 -78.26 2338 -80.89 2348 -0.07 2358 -25.69 2348 -40.83 2358 -0.07 2358 -25.69 2358 -30.25 2378 -0.05 2378 -3.18 -30.25 2388 -0.05 2378 -30.25 -30.25 2389 -0.05 2388 -33.15 2368 -30.25 2408 0.22 2408 120.67 2388 -33.15 2418 120.05 2408 120.05 2418 107.71 2428 0.22 2428 12.05 2418 107.71 2448 0.01 2458 50.89 2448 45.74 2458 0.16 2458 50.89 2448 45.74 2458 0.04 2468 24.88 2	0.87	2318	67°0	73.60	78.88	2308	63.68	32.5
2338 -101.45 2348 0.15 2348 67.44 2358 -0.07 2358 -23.09 2378 -0.05 2368 -23.09 2388 -0.05 2348 -3.15 2398 0.02 2398 98.53 2408 0.22 2408 130.67 2428 0.22 2428 120.05 2438 0.03 2448 67.2 2458 0.11 2448 65.83 2458 0.16 2458 60.83	2338 -101/85 2378 -160.99 2348 0.15 2348 62.44 2348 -88.98 2358 -0.07 2358 -25.09 2358 -30.25 2378 0.08 2368 25.53 2368 -30.25 2378 0.05 2378 -3.89 -3.89 -3.89 2388 0.05 2398 98.53 2398 -7.865 2408 0.22 2408 130.67 2408 10.771 2418 0.22 2418 125.05 2418 107.71 2428 0.03 2438 6.72 2438 84.88 2448 0.11 2448 55.93 2448 45.74 2458 0.04 2458 59.69 2458 71.29 2468 2458 2458 2458 2458 71.29	13.34	2328	77.0	0,000	77.007.	2318	-207.81	2318
2348 0.15 2348 67.44 2358 -0.07 2358 -23.09 2368 0.08 2368 -23.09 2388 -0.05 2378 -3.88 2388 -0.05 2398 -3.15 2408 0.22 2498 130.67 2418 0.22 2418 120.05 2428 0.03 2438 6.72 2448 0.11 2448 55.83 2458 0.16 2458 55.83	2348 0.15 2338 -1820 2338 -88.98 2358 -0.07 2358 -23.09 2358 -30.25 2368 2368 25.53 2368 -3.0.25 2378 -0.05 2378 -3.89 -3.89 2398 0.05 2398 -3.89 -2.08 2408 0.22 2408 12.87 -2.08 2418 0.22 2408 130.67 2408 10.77 2428 0.22 2418 120.05 2418 107.71 2428 0.03 2428 63.18 107.71 2448 0.11 2448 55.93 2448 45.74 2458 0.16 2458 59.69 2448 45.74 2488 0.04 2468 55.93 2448 45.74 2488 0.06 2458 59.69 2448 45.74 2488 0.06 2468 31.79 248 71.29 </td <td>-233</td> <td>2338</td> <td>. 5</td> <td>2330</td> <td>C8: /0!-</td> <td>2328</td> <td>-150.99</td> <td>2728</td>	-233	2338	. 5	2330	C8: /0!-	2328	-150.99	2728
2358 -0.07 2358 -23.09 2368 0.09 2358 -23.09 2378 -0.05 2378 -3.15 2388 -0.05 2398 -3.15 2398 0.2 2398 98.53 2408 0.22 2408 130.67 2428 0.22 2418 120.05 2438 0.03 2448 6.75 2458 0.11 2448 55.83 2458 6.72 56.83	2358 -0.07 2358 -23.09 2358 -30.25 2368 2368 25.53 2358 -3.025 2378 0.08 2378 -3.89 2378 -12.67 2388 -0.05 2388 -3.15 2388 -3.0.25 2398 0.2 2398 98.53 2398 78.05 2408 0.22 2408 130.67 2408 107.71 2428 0.22 2418 120.05 2418 107.71 2438 0.03 2438 6.72 2438 84.86 2448 0.11 2448 55.93 2448 45.74 2458 0.16 2458 59.69 248 45.74 2488 0.04 2468 31.78 31.78 31.79	0.66	23.48	2.5.5.4.5.4.5.4.5.4.5.4.5.4.5.4.5.4.5.4.	23.6	97.87-	2338	98.99	2339
2368 0.08 2358 25.53 2378 0.05 2378 -3.86 2388 -0.05 2378 -3.86 2388 -0.05 2388 -3.15 2408 0.22 2498 98.53 2418 0.22 2418 120.05 2428 0.03 2438 8.72 2448 0.11 2448 55.83 2458 0.16 2458 55.83	2368 2368 25.53 2358 -30.25 2378 0.06 2378 -3.89 41.9 2388 -0.05 2378 -3.15 2368 -30.25 2388 -0.05 2388 -3.15 2388 -26.65 2408 0.22 2408 13.067 2408 78.92 2418 0.22 2408 130.67 2408 107.71 2428 0.02 2418 172.05 2418 107.71 2438 0.03 2438 8.72 2438 84.86 2448 0.11 2448 55.83 2448 45.74 2458 0.16 2458 59.83 2448 45.74 2468 -0.04 2468 -31.79 248 71.29	7.98	2358	2 5	950	62.4	2348	40.83	23.48
2378 2378 2388 -0.05 2388 -0.05 2398 -0.05 2398 -3.15 2408 0.22 2418 0.23 2428 120.05 2438 0.03 2448 0.11 2458 6.72 2458 6.72 2458 6.72 2458 6.72 2458 6.72 2458 6.72 2458 6.72 2458 6.72	2378 0.05 2378 41.9 2388 -0.05 2378 -3.89 2376 12.67 2388 -0.05 2388 -3.15 2388 -28.65 2408 0.22 2408 130.67 2398 78.92 2418 0.22 2408 150.05 2418 107.71 2428 0.22 2428 72.57 2428 107.71 2438 0.03 2438 8.72 2438 84.86 2448 0.11 2448 55.83 2448 45.74 2458 0.16 2458 59.89 2458 71.29 2468 -0.04 2468 -31.79 248 71.29	15.62	2368	500	2220	25.00	2358	-30.25	2358
2388 -0.05 2316 2388 -0.05 2388 2398 0.2 2398 2408 0.22 2408 2418 0.29 2418 2428 72.57 2438 0.03 2448 2458 6.72 2458 6.58 2458 55.83	2388 -0.05 2316 -3.05 -3.15 2376 12.67 2388 -0.05 2388 -33.15 2388 -28.65 2408 0.22 2408 130.67 2408 78.92 2418 0.22 2418 120.05 2418 107.71 2428 0.22 2428 72.57 2428 84.86 2438 0.03 2438 8.72 2438 84.86 2446 0.11 2448 55.83 2448 45.74 2458 0.16 2458 59.69 2458 71.29 2468 -0.04 2468 -31.79 248 71.29	18.39	2378	80.0	2220	200	2368	41.9	2368
2398 0.2 2398 98.53 2408 0.22 2408 130.67 2418 0.29 2418 120.05 2428 0.22 2428 72.57 2438 0.03 2438 8.72 2458 0.11 2448 55.83 2458 6.06 55.83	2398 0.2 2398 -33.15 2388 -28.65 2408 0.22 2409 130.67 2408 78.92 2418 0.22 2418 120.05 2418 107.71 2428 0.22 2428 107.71 107.71 2438 0.03 2438 87.25 2438 84.86 2446 0.11 2448 55.83 2448 45.74 2458 0.16 2458 59.69 2458 71.29 2468 -0.04 2468 -31.79 248 71.29	4	2388	3 S	23.6	8.5	2378	12.87	2378
2408 0.22 2408 (30.67 2418 0.29 2418 (20.05 2428 0.22 2428 72.57 2438 0.03 2448 6.72 2458 0.11 2448 55.83 2458 55.83	2408 0.22 2409 130.67 2389 78.92 2418 0.22 2408 130.67 2408 89.18 2428 0.22 2418 107.71 107.71 2438 0.03 2438 6.72 2428 84.86 2448 0.11 2448 55.83 2448 45.74 2458 0.16 2458 59.69 2458 71.29 2468 -0.04 2468 -31.79 248 71.29	21.18	2398	2 6	2308	- S. 13	27,88	-28.65	2388
2418 0.29 2418 120.05 2428 0.22 2428 72.57 2438 0.03 2438 8.72 2448 0.11 2448 55.83 2458 60.16 2458 59.83	2418 2400 130.87 2400 69.18 2428 0.22 2418 120.05 2418 107.71 2428 0.22 2428 107.71 107.71 2438 0.03 2438 8.72 2428 84.86 2448 2448 55.83 2448 45.74 2458 59.69 2458 71.29 2488 -0.04 2468 -31.79 2458	49.0	2408	, 2	007	2.5	2398	79.92	2398
2428 0.22 2428 120.05 2438 0.03 2438 6.72 2448 0.11 2448 55.83 2458 0.16 2458 59.83	2410 0.23 2418 120.05 2418 107.71 2428 0.22 2428 72.57 2428 84.86 2448 0.03 2438 6.72 2438 3.78 2448 0.11 2448 55.93 2448 45.74 2458 0.16 2458 59.69 2458 71.29 2488 -0.04 2468 -31.78 248 63.00	25.2	277	7 8	9047	130.67	2408	89.18	907.
2428 0.22 2428 72.57 2438 0.03 2438 6.72 2448 0.11 2448 55.83 2458 0.16 2458 59.83	2420 0.22 2428 72.57 2428 84.86 2438 0.03 2438 6.72 2438 84.86 2448 0.11 2448 55.93 2448 45.74 2458 2458 59.69 2458 71.29 2488 -0.04 2468 -31.78 248	ξ.;	2410	₹7.0°	2418	120.05	2418	107 74	240
2438 0.03 2438 6.72 2446 0.11 2448 55.83 2458 0.16 2458 59.83	2438 0.03 2438 6.72 2438 3.78 2448 0.11 2448 55.93 2448 45.74 2458 2458 59.69 2458 71.29 2488 -0.04 2468 -31.78 2288	17.1	7478	0.22	2428	72.57	2428	00 70	2418
2448 0.11 2448 55.93 2458 0.16 2458 59.89	2448 0.11 2448 55.93 2448 45.74 2458 0.16 2458 59.69 2458 45.74 2468 -0.04 2468 -31.79 2458 71.29	7.19	2438	0.03	2438	6.72	2438	8.5	2428
2458 0.16 2458 59.89	2458 0.16 2458 59.89 2458 71.29	5.21	2448	0.11	2448	55.83	2440	E ;	2438
	2488 -0.04 2488 -31.79 2488	14.12	2458	0.16	2458	25.05	2450	5.7	2448
2468 -0.04 2468	6.10	24.15	2488	8	2088	24 70	2436	71.20	2458

SUBSTITUTE SHEET (RULE 26)

Components of possible prediction equations from multivariate regression analyses. Table 6b.

	, , ,			DIRECTIONS OF ONLY THEREOF IN VIVO	
!	PLS (2,5,6)	PCR (2,6,6	(9'9)	PLS (2.6.6)	2.6.61
Coefficient	Wavelength	Coefficient	Wavelength	Coefficient	Wavelength
59.77		40.56		28	
-96.28	801.	-181.5	\$.78.7	5
7,56	1118	12.91	1118	-	8 1
12.25	1128	22.04	1128	88	128
8.85	138	19.51	1138	76	95.5
6.74	1148	8.19	1.48	208	8 5
11.89	158	5.29	1158	6.24	55
4.45	± 58	-0.82	1168	0.43	2 2
10.08	178	-1.1-	1178	89.5	1178
28.8	1188	37.4	1188	-15.1	883
-20.43	1.98	-28.13	1198	-10.61	961
8.5	202	28.03	82	-15.86	1208
-15.55	1218	-35.64	1218	-13.16	1218
2.41	1228	-13.39	1228	2.03	1228
6.62	238	0.89	1238	6.37	1238
o !	1248	14.13	1248	20.2	1248
/4/	PCZ	17.48	1250	5.90	1258
-1.32	20.0	1.7.	1268	-0.25	1288
65.7-	1278	.22.67	1278	8 3.	1278
æ :	1288	8	1288	0.15	1288
3.48	1298	9.23	1 28	3.72	1298
. S. C	306	13.17	900	4 .38	1308
6.23	1318	15.6	1318	6.03	1318
5.45 5.45	1328	25.91	1328	9.03	1328
9777	1356	1/04	1338	5	1330
24.61	9	51.12	2	13.51	1348
70.0	38	9.	1358	0.26	1358
-23.89	1368	-88.33	1368	-13.01	1368
-29.88	1378	-68.78	1378	-8.13	1378
-18.97	1388	5.08	1388	4.1-	1388
23.92	1398	32.14	1398	16.08	1398
60.7	408	78.51	1408	32.00	1408
55.51	1418	9 0.64	1418	3.	8171
7		!			

Components of possible prediction equations from multivariate regression analyses. Table 6b.

Conflictert PCR (2.6.4)	estibility of dr	Digestibility of dry matter in vitro		Digestibility of dry matter in vivo	ry matter in vivo	
1446 11.15 1438 -18.94 1448 1438 -18.94 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 1448 -18.24 -17.44 1498 -17.54 1498 -17.54 1498 -17.54 1498 -17.54 1498 -17.54 1518 -17.54 -17.54 1518 -17.54 -17.54 1518 -17.54 -17.54 1518 -17.54 -17.54 1518 -17.54 -17.55 -17.54 -17.5		_				
1446 10.5 1448 -19.24 1458 -14.54 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 1458 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 -16.15 15.16 15.16 -16.15 15.16 -16.15 15.16	-28.21	1438	-11.15	1438	18.64	8271
1458 18.31 1458 -16.15 1488 -3.82 1488 -16.15 1488 -3.82 1488 -3.7 1488 -7.54 1488 -0.75 1498 -7.43 1489 -7.65 1508 -7.43 1489 -7.65 1518 -5.87 1508 -8.41 1528 -7.53 1539 -7.65 1538 -7.63 1539 -3.63 1548 -7.74 1578 -3.63 1558 -7.74 1578 -3.63 1589 -7.74 1578 -3.63 1598 -7.53 1589 -5.44 1609 -7.74 1578 -5.77 1610 -7.62 1589 -5.48 1629 -7.63 1689 -5.77 1639 -7.74 1629 -6.53 1639 -7.74 1629 -6.53 1639 -7.62 1689	-32.57	1448	10.5	1448	-19.24	87
(488 -3.02 1448 3.7 (488 -75.44 1448 0.75 (498 -75.44 1498 -7.65 (508 -75.49 1508 -7.65 (518 -8.41 10.65 -7.65 (518 -7.54 1508 -7.65 (528 -7.57 1538 -7.65 (528 57.83 15.84 -7.65 (528 57.83 15.84 -7.65 (528 57.83 15.84 -7.65 (528 57.83 15.84 -7.65 (528 57.74 15.84 -7.65 (528 -7.72 15.78 -3.09 (529 -7.65 15.84 -5.77 (609 -7.65 15.89 -6.84 (609 -7.65 16.89 -6.44 (610 -7.65 16.89 -6.44 (620 -7.72 16.89 -6.49 (630 16.89 16.8	-28.08	1458	16.31	1458	-16.15	857
1478 -18.46 1478 1065 1488 -25.14 1488 10.75 1508 -75.43 1509 -9.41 1508 -75.77 1538 -7.65 1539 -75.77 1538 -7.65 1539 -7.53 1538 -8.06 1548 17.83 1538 -8.06 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1558 27.03 1538 4.56 1600 -1.62 1608 -6.57 1601 -1.63 1608 -6.57 1602 -1.63 16.03 -6.57 1603 -1.64 10.04 -6.57 1604 -1.63 16.04	1.48	1468	-3.82	1468	3.7	897
1488 -25.14 1489 -0.75 1488 -74.43 1489 -7.65 1518 -5.8.78 1518 -9.06 1528 -5.27 1528 -8.41 1539 -7.63 1538 -6.21 1539 17.83 1538 -6.28 1558 27.42 1538 -6.57 1598 -27.42 1538 -6.57 1598 -5.77 1538 -6.48 1609 -5.77 1698 -6.57 1609 -5.77 1698 -6.57 1609 -5.77 1698 -6.48 1609 -6.65 1608 -6.57 1609 -6.59 1608 -6.57 1609 -7.65 1698 -6.40 1619 -6.57 1698 -6.40 1629 -6.69 -6.40 -6.40 1629 -7.34 16.98 -6.10 1629 -7.34 16.98 <td>18.21</td> <td>1478</td> <td>-16.48</td> <td>1478</td> <td>10.65</td> <td>1478</td>	18.21	1478	-16.48	1478	10.65	1478
1448 -7443 1496 -7.65 508 -75.40 1516 -0.05 518 -25.77 1528 -3.21 528 -7.63 15.88 -3.02 528 52.88 15.88 -3.03 528 -27.42 1528 -3.03 528 -27.42 1528 -3.03 528 -27.42 1528 -3.03 528 -27.42 1528 -3.03 528 -27.42 1528 -3.03 528 -27.42 1528 -0.87 528 -2.81 1628 -0.87 608 -3.08 1608 -0.65 609 -3.08 1608 -0.65 609 -3.08 1608 -0.65 609 -3.08 1608 -0.87 609 -3.08 1608 -0.87 609 -3.08 1608 -0.18 609 -3.08 1608 -3.17 778 -2.54 1728 -3.17 778 -2.54 1748 -3.17 778 -2.64 1788 -3.137 778 -3.27 1788 -3.137 778 -3.28 1788 -3.137 778	59.0-	1488	-25.14	1488	0.75	1489
15.08	-22.89	1498	-74.43	1498	-7.65	887
1516	-23.44	208	-75.49	506	-9.41	805
1528 -7.5.7 1528 -5.21 1538 -7.63 1538 -3.03 1548 -7.63 1558 4.56 1558 -2.103 1558 15.5 1588 -2.742 1588 -3.03 1598 -5.77 1598 -5.77 1598 -5.76 1658 -5.77 1609 -6.65 16.36 16.36 -6.57 1618 -7.36 16.38 -6.57 -6.57 1628 -3.03 1603 -0.65 -6.77 1639 -1.62 1618 -0.87 16.48 0.05 1648 1638 -6.57 16.28 13.12 16.28 13.12 1648 1638 1638 16.28 13.12 13.12 14.01 16.88 -6.19 16.88 14.01 16.88 -6.19 16.88 -6.19 16.88 -6.19 16.88 -6.19 16.88 -6.19 16.88 -6.19 17.	-15.74	1518	-58.78	1518	-9:09	1518
15.46 17.63 15.36 -3.69 15.46 17.64 17.63 15.56 15.56 15.56 15.56 15.56 15.56 15.56 15.56 15.65 15.66 17.66 17.6	6 0.6-	1528	.25.77	1528	-5.21	1528
17.83 15.48 4.56 15.84 17.83 15.58 15.58 15.85 27.02 15.58 2.31 15.86 -27.42 15.69 15.69 15.86 -27.69 15.69 -2.77 15.86 -2.81 16.09 -0.65 16.16 -2.81 16.18 -0.87 16.28 -2.81 16.28 -0.87 16.28 -2.81 16.28 -0.87 16.28 -2.81 16.28 -0.87 16.28 -2.81 16.69 -2.81 17.88 -2.81 17.88 -2.1.21 17.88 -2.68 17.89 -2.1.21 17.89 -2.58 17.89 -2.1.21 17.80 -2.58 17.89 -2.1.21 17.80 -2.58 17.89 -2.1.21 17.80 -2.68 17.89 -2.1.21 17.80 -2.68 17.89 -2.1.21 17.80 -2.1.34 17.89 -2.1.21 17.80 -2.1.34 17.89 -2.1.21 17.80 -2.1.37 17.89 -2.1.37 17.80 -2.1.37 17.89 -2.1.37 17.80 -2.1.37 17.89 -2.1.37 17.80 -2.1.37 17.89 -2.1.37 17.80 -2.1.37 -2.1.37 17.80	-2.8	1538	.7.83	1538	3.63	1538
1658 52.88 1558 15.8 1588 -27.42 1558 -2.31 1588 -42.59 1589 -6.48 1598 -5.77 -6.48 -6.48 1598 -5.77 -6.48 -6.48 1608 -6.56 16.69 -6.48 1609 -7.65 16.18 -0.65 1610 -7.81 16.98 -0.65 1628 -9.18 16.39 3.42 1639 -9.18 16.39 3.42 1648 13.39 16.48 0.06 1658 15.39 16.49 0.06 1658 15.39 16.69 -4.01 1689 -77.73 16.99 -4.01 1709 -77.73 16.99 -4.01 1709 -77.73 17.28 -21.21 1709 -77.73 17.28 -21.21 174 -7.24 17.49 -5.24 178 -7.24	10.62	1548	17.83	1548	4.56	5.6
1586 21,09 1566 2,31 1578 -27.42 1576 -3.09 1586 -2.77 -3.09 1586 -2.77 -3.09 1586 -2.77 -3.09 1686 -1.62 1686 -0.65 1618 -2.81 1628 -0.87 1638 -2.81 1638 -0.87 1648 1648 1638 -0.87 1648 1648 1648 0.04 1658 1658 -2.83 1688 -78.36 1688 -3.19 1709 -77.73 1699 -3.17 1709 -4.3 7.73 1708 -18.38 1709 -4.3 7.73 1708 -18.38 1709 -4.5 1708 -11.67 1709 -4.5 1708 -11.67 1709 -4.5 1708 -0.49 1709 2.031 1708 -0.49 1709 -2.68 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1709 -2.13 1708 -0.49 1700 -2.13 1708 -0.40 1700 -2.13 1708 -0.40 1700 -2.13 1708 1700 -2.13 1708 1700 -2.13 1708 1700	28.78	1558	52.68	1558	15.5	855
1578 -27.42 1578 -3.09 1588 -42.59 1588 -5.77 1608 -5.06 1608 -6.46 1608 -3.09 1608 -6.57 1618 -1.62 1618 -0.65 1628 -2.81 1628 0.24 1639 -9.16 1639 3.42 1638 -9.18 1639 3.42 1648 1639 3.42 13.12 1658 1639 1639 -3.42 1658 1639 1639 -3.42 1698 -77.73 1698 -9.19 1709 -43.87 1708 -18.38 1718 21.34 1718 21.21 1739 -4.56 1738 -21.21 174 -2.5 1739 -21.21 1758 -2.1 174 -5.24 1768 -2.6 1768 -0.49 1778 -2.1 1778 -0.49 1778 -2.1 1778 -0.49 1778 -2.1 1778 -0.49 1778 -2.1 1778 -0.49 1778 -2.1 1778 -0.49	5.02	1568	21.09	1568	2.31	1568
1588 -42.59 1588 -5.77 1598 -63.69 1598 -6.48 1608 -0.65 -6.65 -6.48 1618 -1.62 1618 -0.65 1628 -2.81 1628 0.24 1639 -9.16 1639 3.42 1639 -9.16 1639 3.42 1648 61.39 1658 13.12 1658 1659 13.12 13.12 1668 -78.36 1688 -8.19 1676 -77.39 1688 -8.19 1709 -43.87 1708 -18.39 1718 -25.6 1728 -31.77 173 -40.51 173 -21.21 176 -25.6 175 -2.24 1778 -2.54 -2.24 1778 -2.24 -2.24 1778 -2.24 -2.24 1778 -2.24 -2.24 1778 -2.24	8 .8	1578	-27.42	1578	-3.09	1578
1598 -53.69 1598 -6,46 1609 -3.05 1609 -0,65 1618 -3.05 1609 -0,65 1619 -2.81 1618 -0,87 1638 -9.18 1639 0.24 1638 -9.18 1639 0.24 1648 1639 0.24 0.24 1658 16.39 1689 -0.81 1669 -77.73 1689 -3.19 1709 -77.73 1699 -3.19 1718 21.34 1708 -18.39 1718 22.3 1718 2.17 1738 -40.51 1728 -21.21 1748 -25.8 1738 -21.21 1778 -25.4 -11.67 1778 -26.4 1768 -0.49 1778 -21.21 -11.67 1778 -21.21 -11.67 1778 -21.21 -11.67 1778 -26.8	-18.09	1588	42.58	1588	-5.77	1588
1609 -3.05 1609 -0.65 1616 -1.62 1618 -0.87 1628 -2.81 1628 0.24 1638 -9.18 1639 3.42 1648 13.81 1648 0.24 1658 61.39 1658 13.12 1668 -79.36 1688 -8.19 1708 -77.73 1698 -3.19 1708 -43.87 1708 -18.39 1718 21.34 1718 2.17 1738 -40.51 1728 -31.77 1738 -40.51 1738 -5.24 1769 -4.55 1778 -5.24 1778 -7.73 178 -5.24 1778 -7.73 178 -5.24 1748 -7.55 1778 -5.24 1769 -7.55 1778 -5.24 1778 -7.73 178 -6.49 1778 -7.21 178	. 0 .28	9651	£.8		-9.48	1598
1616 -1.62 1618 -0.87 1628 -2.81 1628 0.24 1638 -9.18 1639 3.42 1648 13.81 1648 0.96 1658 15.96 1668 28.91 1668 -70.36 1688 -8.19 1690 -77.73 1698 -3.19 1708 -43.87 1708 -18.38 1718 21.34 1718 2.17 1728 -25.8 1728 -21.21 1748 -25.8 1738 -21.21 1756 2.64 1768 -0.49 1778 2.091 1778 -0.49 1778 2.091 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 </td <td>98.99</td> <td>89</td> <td>8</td> <td>1608</td> <td>-0.65</td> <td>609</td>	98 .99	8 9	8	1608	-0.65	609
1628 0.24 1638 -2.81 1628 0.24 1648 13.81 1648 0.96 1658 16.39 1658 13.12 1668 168 28.91 1676 101.05 168 -4.19 1680 -77.73 169 -4.19 1708 -43.87 1708 -18.39 1718 21.34 1718 2.17 1728 -40.51 1728 -21.21 1738 -40.51 1738 -21.21 1748 -25.8 1738 -21.21 1756 -26.11 1738 -21.21 1778 -26.24 -11.67 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 2.09.1 1778 -0.49 1778 21.37 -0.4	-3.82	1618	-1.62	1618	-0.87	1818
1638 9.18 1639 3.42 1648 13.81 1648 0.86 1658 16.39 165.8 13.12 1668 16.39 168.1 28.91 1676 101.05 168 -40.1 1680 -77.7 169 -4.19 1700 -43.87 1708 -18.38 1718 21.34 1718 2.17 1728 -40.51 1728 -21.21 1738 -40.51 1738 -21.21 1746 -28.11 1748 -5.24 1778 2.68 176 -0.49 1778 2.091 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 1778 21.37 1778 -0.49 <	-3.56	1628	-2.81	1628	0.24	1628
1648 13.81 1648 0.86 1658 13.12 1668 13.12 1668 13.12 1668 13.12 1678 16	0.65	1636	9.18	1638	3.42	1638
1658 1658 13.12 1668 28.51 1676 170.05 1688 28.51 1684 -77.73 1698 -3.4 1708 -43.87 1708 -18.38 1718 21.34 1718 2.17 1728 -40.51 1728 -21.21 1748 -28.11 1748 -5.24 1778 2.68 1768 -0.49 1778 20.91 1778 21.37 1778 20.91 1778 21.37 1778 20.91 1778 21.37 1778 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1779 20.91 1778 21.37 1770 20.91 1778 21.37 1770 21.37 1	0.5	1648	13.81	1848	0.86	1648
1008 159.6 1688 28.91 1678 44.01 1688 -77.73 1698 -3.4 1708 -18.38 -18.38 1708 -25.8 1728 -21.21 1738 -26.14 1748 -5.24 1768 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778 1778 -5.24 1778	23.87	829	61.39	859	13.12	1658
1676 101.05 1678 44.01 1684 -77.73 1688 -6.19 1696 -77.73 1699 -34 1708 -43.87 1708 -18.38 1718 21.34 1718 2.17 1728 -40.51 1728 -31.77 1738 -40.51 1738 -21.21 1748 -28.11 1748 -5.24 1756 2.68 1768 -0.49 1778 20.91 1778 21.37 1788 13.25 1788 13.25	54.92	88	159.6	88 98 98 98 98 98 98 98 98 98 98 98 98 9	28.91	1999
1696 -77.73 1698 -8.19 (1696 -7.77) 1698 -8.19 (1706 -7.18.36 (1706 -18.36 (1706 -18.36 (1706 -18.36 (1706 -18.36 (1706 -18.36 (1706 -18.36 (1706 -18.36 (1706 -19.36 (1706 -1	78.84	9/91	8.5	16/8	44.0	1678
1708	-13.9	889	8, 2,	200	-8.10 -0.10	1688
1708 -43.87 1778 21.34 1778 -21.7 1738 -21.71 1748 -28.11 1758 -17.8 1759 -21.21 1759 -21.21 1759 -21.21 1759 -21.21 1759 -11.67 1779 -0.49 1778 21.37 1789 13.59 1788 13.25	Z 5	960	27.77	882	ર ્જે :	1698
1718 21.34 1728 -31.77 1738 -40.51 1748 -21.21 1758 -4.55 1769 -2.64 1778 -0.49 1778 -0.49 1778 21.37 1788 13.59 1788 13.25	3.	3	43.87	82	-18.38	1708
1728 -31.77 1738 -40.51 1738 -21.21 1748 -28.11 1748 -5.24 1758 -4.55 1758 -11.67 1778 20.91 1778 21.37 178 13.59 1788 13.25	24.48	1718	21.3	1718	2.17	1718
1738 -40.51 1738 -21.21 1748 -28.11 1748 -5.24 1758 -4.55 1758 -11.67 1769 2.68 1769 -0.49 1778 20.91 1778 21.37 1788 13.59 1786 13.25	-17.91	1728	-25.8	1728	-31.77	1728
1748 -28.11 1748 -5.24 1758 -4.55 1758 -11.67 1769 20.81 1778 20.49 1778 20.81 1778 21.37 1788 13.59 1788 13.25	0.0	1738	40.51	-738 -238	-21.21	1738
1758 -4.55 1758 -11.67 1768 2.68 1768 -0.49 1778 20.91 1778 21.37 1788 13.59 1786 13.25	-29.25	1748	-28.11	1748	-5.24	1748
1768 2.68 1768 -0.49 1778 20.91 1778 21.37 1788 13.59 1786 13.25	-16.33	1758	\$3 **	1758	-11.67	1758
1778 20.91 1778 21.37 1788 13.25	0.43	1768	2.68	1788	-0.49	1768
1788 13.59 1788 13.25	28.21	1778	20.91	1778	21.37	1778
	18.92	1788	13.59	1788	13.25	1788

Components of possible prediction equations from multivariate regression analyses. Table 6b.

igestibility of at	Digestibility of dry matter in vitro		Digestibility of d	Digestibility of dry matter <i>in vivo</i>	
PLB (2,5,6)		PCR (2,6,6)			PLS (2,6,6)
Coefficient	Wevelength	Coefficient	Wavelength	Coefficient	Wavelength
-2.44	808	7.17	1608	S. T	1808
-2.72	. 1818	-15.36	1818	-2.3	1818
-5.84	1828	-29.4	1828	-3.37	1628
4.37	1838	-16.21	1638	9	1838
-8.79	1848	2.3	-848	-2.23	1848
-7.72	1858	-0.87	1858	3.78	1858
-29.03	1668	-21.29	1868	-9.61	1888
-98.16	1878	-62.33	1878	-34.56	1878
-116.18	1888	-102.15	1888	-52.89	1888
117.59	1898	211.27	1898	38.2	1898
185	1909	204.51	1908	66.78	1906
33.91	1918	-3.12	1918	28.1	1918
35.31	1928	18.14	1928	3.79	1928
23.7	1938	35.39	1938	-19.45	1838
-9.28	1948	-8.24	1948	₩.	1948
35.73	858	-11.32	1958	15.85	1958
28.58	1968	37.15	1968	13.49	1988
10.68	1078	4 .28	1978	2.03	1978
10.98	1968	-61.81	888	0.57	1988
65.12	1998	-72.2	1998	31.07	1996
63.13	2008	-60.31	2008	38.57	2008
7.23	2018	37.37	2018	-1.21	2018
0.89	2028	183,21	2028	-0.38	2028
-10.85	2038	158.68	2038	-14.51	2038
-84.48	2048	-2.09	2048	-54.72	8 7 02
-122.91	2058	-178.03	2058	-68.29	2068
35.85	2068	-104.9	2068	-1.69	2068
7. E.E.	2078	-1.7	2078	37.55	2078
28.83	2088	62.28	2088	27.17	2088
18.03	2008	54.26	208	16.01	2098
203	2108	14.14	2108	15.52	2108
-9.58	2118	-40,31	2118	7.68	2118
9.79	2128	2.34	2128	13.25	2128
23.04	2138	26.94	2138	16.49	2138
-10.93	2148	-31,56	2148	-6.42	2148
-16.87	2158	3.05	258	-9.12	2158

	PI S /2 8 C)	Wandandh	OF TO	21/18	2188	2199	2208	2218	5 23	2238	2248	2258	2268	27.8	2288	8822	2308	8167	23.88 82.52	2348	2358	2368	2378	2368	2398	2408	2418	2428	2438	2448	2458
Digestibility of dry matter in vivo		Coefficient	A3 CF.	3 5	8.71-	4	4.87	-30.89	7.6. 6.6.	8 5	8/3	S (0)	77.08	25.55 55.55	3 5	96.5.	2 2 2	48.6	37.78	-48.16	-7.88	18.34	17.8	. 8	-27.54	-50.39	-18.09	17.75	877	17.11.	/R.C
Digestibility of	(9'9'	Wavelength	2178	2.58	3 5	8 e	9 5	3226	2,75	2.5	22.6	286	22.00	2288	2288	2308	2318	2328	2338	2348	2358	2368	9/67	D007	9867	2408	2418	2470	2448	2458	34
	PCR (2,6,6)	7	-107.52		-11 17	2) (4	73.68) ()	100,18	53.32	61.52	48.93	-9.10	25.1	47.83	-23.3	-73.02	-23.74	13.84 23.84	79:17: T	87.11- 27.00	29.59 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50	25.03	2.5	1.77	08:07-	75.00	58.83	8.48	£3.	, , , , ,
Digestibility of dry matter in vitro	_ `	Wavelength	2178	2188	2198	2208	2218	8222	2238	2248	2258	89ZZ	8722	2288	86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 86 72 72 72 72 72 72 72 72 72 72 72 72 72	2308	23.68	2328	2338	25.5	2368	2378	2388	23.08	8096	2418	2428	2438	2448	2458	
gestibility of dr	PLS (2,6,6)	Cocinciera	63.63	-14.5	4.0	-7.15	-48.95	-18.22	86.33	-24.11	55.00	10.08	52.16	-89.38	-109.89	- J. S.	3.5	13.7	-58 tA	-21.28	10.4	32.53	35.58	.21.25	-70.01	-16.86	91.68	14.84	-11.88	5.35	

Descriptions of forages used in Table 8.

ample in able 8	Genus	Species	Variety	Contron name	Part of plant	Process undergone	Stage of maturity	Regrowth
- in a so so	Pankum Pankum Pankum Pankum Pankum	coloratum maximum coloratum maximum coloratum var Makerikarlense maximum var. trichogiume	Kabudabula CP1 16796 Coloniso Bambatsi Hamii Burnett	Makarikari grass Gulnea grass Makarikari grass Gulnea grass Makarikari grass Green Panic	serial serial serial	dried and chaffed dried and chaffed dried and chaffed dried and chaffed dried and chaffed dried and chaffed dried and chaffed	mid bloom (9 weeks' regrowth) vegelative regrowth (4 weeks') mid bloom (1 month's regrowth) early bloom (6 weeks' regrowth) mid bloom (6 weeks' regrowth) mid bloom (4 weeks' regrowth)	mid bloom - regrowth vegelative regrowth mid bloom - regrowth earty bloom - regrowth mid bloom - regrowth mid bloom - regrowth mid bloom - regrowth
_					_			

Examples of energy required to shear, digestibility of dry matter in vivo, forage consumption constraint (FCC), and voluntary feed consumption (VFC)

Predicted using the calibration equation from stepwise regression analysis (Table 6a)

Predicted using the calibration equation from stepwise regression analysis (Table 6a). Predicted using predicted energy required to shear, and the relationship between energy required to shear and FCC.

Calculated from predicted FCC and predicted digestibility of dry matter in vivo. Abbreviations used: organic matter (OM), metabolic body weight (MBW) = BW^{0.75}

5

THE CLAIMS of the invention are as follows:

- A method for determining a biomechanical property of a feed, the method comprising the steps of:
- (a) subjecting the feed to infrared radiation to obtain spectral data;and
 - (b) using the spectral data to determine the biomechanical property;

whereby, the biomechanical property of the feed is determined on the basis of the bond energies of the chemical constituents of the feed.

- A method according to claim 1 wherein the biomechanical property of the
 feed is determined directly from the spectral data.
 - 3. A method according to claim 1 wherein the spectral data is used to determine another property of the feed and the other property is used to determine the biomechanical property on the basis of a correlation between the other property and the biomechanical property.
- A method according to claim 3 wherein the other property is ADF content,
 NDF content or lignin content.
 - 5. A method according to claim 1 or claim 2 wherein the spectral data is a reflectance spectrum over a predetermined range of wavelengths.
- 6. A method according to claim 5 wherein the predetermined range is approximately 700nm to 3000nm.
 - 7. A method according to claim 5 wherein the predetermined range is approximately 1100nm to 2500nm.

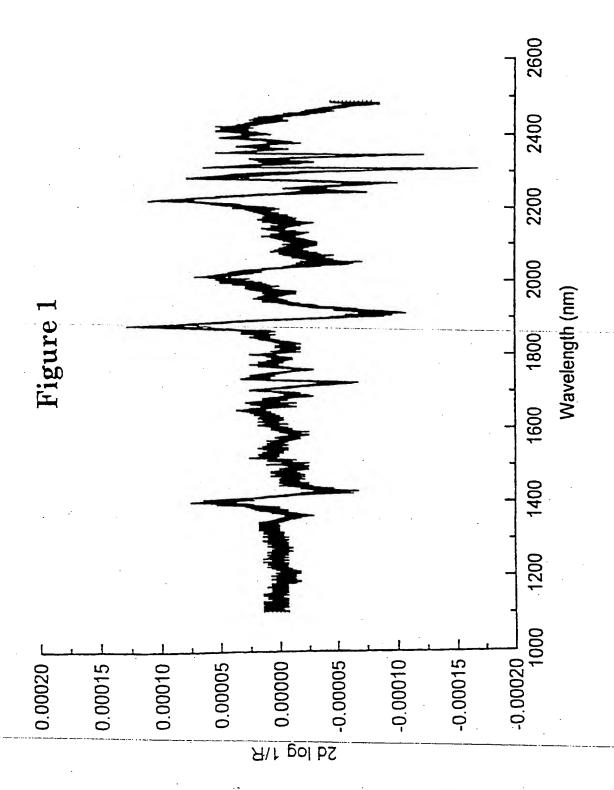
- 8. A method according to any one of claims 5 to 7 wherein the data obtained for the spectral range of approximately 1850nm to 1970nm is disregarded.
- 9. A method according to any one of claims 5 to 8 wherein the spectral data is recorded at 2nm intervals over the predetermined range.
- 5 10. A method according to claim 1 or claim 2 wherein the reflectance reading is taken at a combination of wavelengths.
 - A method according to claim 10 wherein the combination of wavelengths is selected from the group comprising: 1168nm, 1458nm, 1598nm, 1718nm, 1828nm, 2048nm, 1138nm, 2018nm, 2128nm, 2408nm, 1268nm, 1588nm, 1728nm, 2278nm, 1158nm, 1238nm, 1668nm, 1908nm, 2248nm, 1698nm
- 1728nm, 2278nm, 1158nm, 1238nm, 1668nm, 1908nm, 2248nm, 1698nm, 1748nm, 1918nm and 2158nm.
 - 12. A method according to claim 10 wherein the combination of wavelengths is 1168nm, 1458nm, 1598nm, 1718nm, 1828nm and 2048nm and the biomechanical property is shear energy.
- 15 13. A method according to claim 10 wherein the combination of wavelengths is 1268nm, 1588nm, 1728nm and 2278nm and the biomechanical property is compression energy.
- 14. A method according to claim 10 wherein the combination of wavelengths is
 1138nm, 2018nm, 2128nm and 2408nm and the biomechanical property is
 comminution energy.
 - 15. A method for determining a biomechanical property of a feed, the method comprising the steps of:
 - (a) subjecting the feed to infrared radiation to obtain spectral data;and

(b) comparing the spectral data obtained in (a) with a calibration equation to determine the biomechanical property;

whereby, the biomechanical property of the feed is determined on the basis of the bond energies of the chemical constituents of the feed.

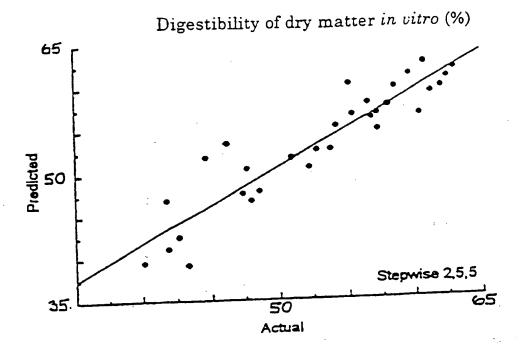
- 5 16. A method according to claim 15 wherein the calibration equation is $y_1 = 19.95 + 10239.46 R_{1168} + 3623.49 R_{1458} 4255.61 R_{1598} 5319.88 R_{1718} + 5148.38 R_{1828} + 2452.05 R_{2048}$ and the biomechanical property is shear energy(y₁).
- 17. A method according to claim 15 wherein the calibration equation is $y_2 =$ 231.42 + 18224.74 R₁₁₃₈ 4955.12 R₂₀₁₈ 3005.37 R₂₁₂₈ + 4290.18 R₂₄₀₈ and the biomechanical property is comminution energy (y_2).
 - 18. A method according to claim 15 wherein the calibration equation is $y_3 = -0.71 911.04 R_{1268} + 112.57 R_{1588} 79.48 R_{1728} 28.02 R_{2278}$ and the biomechanical property is compression energy (y_3) .
- 15 19. A method according to any one of claims 15 to 18 wherein the calibration equation is determined from laboratory data establishing a correlation between reflectance and the biomechanical property.
 - 20. A method according to any one of claims 1 to 19 wherein an additional property of the feed is also determined.
- 20 21. A method according to claim 20 wherein the additional property of the feed is digestibility of dry matter *in vivo* or *in vitro*.
 - 22. A method for determining feed quality, the method comprising the steps of:
 - (a) subjecting the feed to infrared radiation to obtain spectral data;

- (b) using the spectral data to determine a biomechanical property of the feed; and
- (c) using the biomechanical property obtained in step (b) to determine feed quality;
- whereby, the biomechanical property of the feed and thus feed quality is determined on the basis of the bond energies of the chemical constituents of the feed.
 - 23. A method according to claim 22 wherein the feed quality is determined as a measure of voluntary feed consumption (VFC).
- 10 24. A method according to claim 22 wherein the feed quality is determined as a measure of forage consumption constraint (FCC).
 - 25. A method substantially as herein described with reference to the description of the examples.
- 26. A spectrometer configured to carry out the method according to any one of
 15 claims 1 to 21 wherein the spectrometer is adapted to receive a sample of feed and determine a biomechanical property of the feed.
 - 27. A spectrometer configured to carry out the method according to any one of claims 22 to 24 wherein the spectrometer is adapted to receive a sample of feed and determine the quality of the feed.
- 20 28. A spectrometer according to claim 26 or 27 further comprising a data processing means for determining the biomechanical property or the quality of the feed.



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Figure 2a



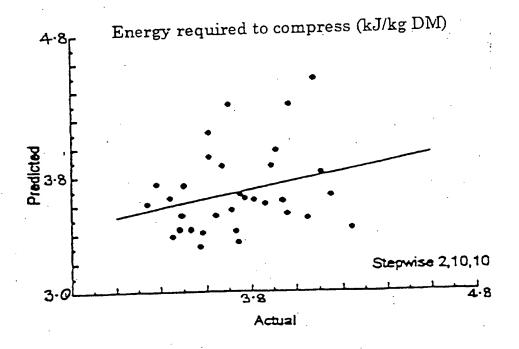
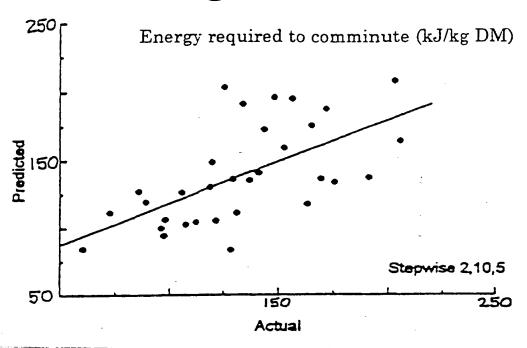
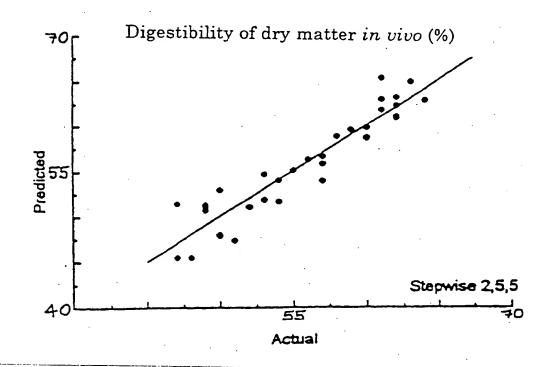


Figure 2a (cont'd)





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Figure 2a (cont'd)

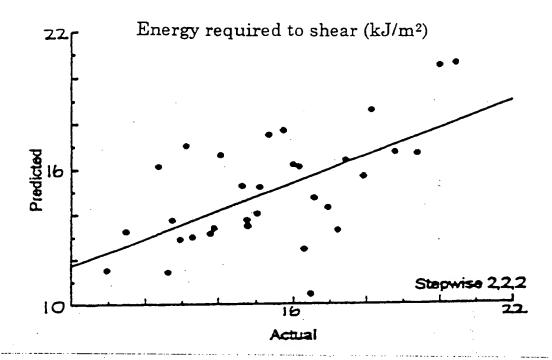
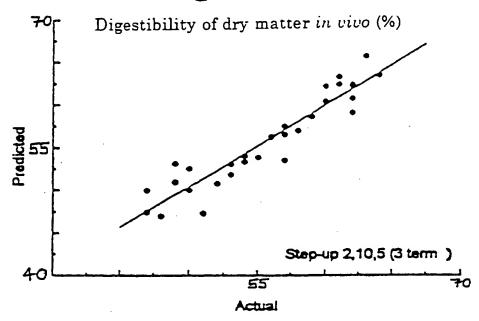
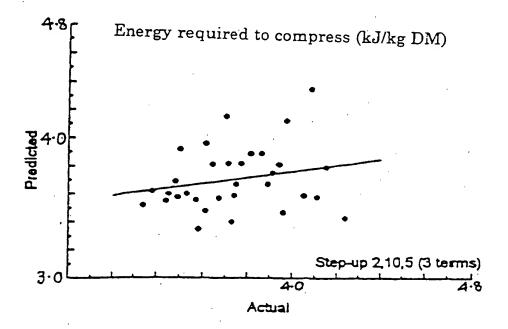
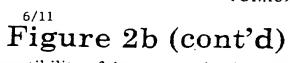
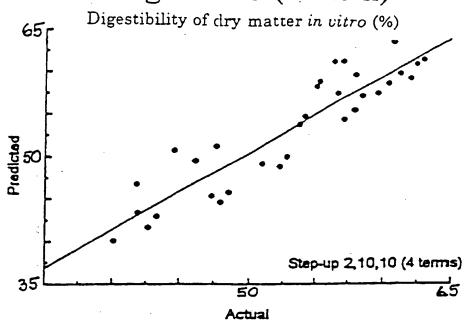


Figure 2b









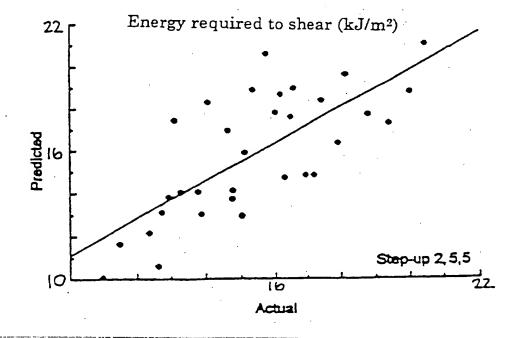


Figure 2b (cont'd)

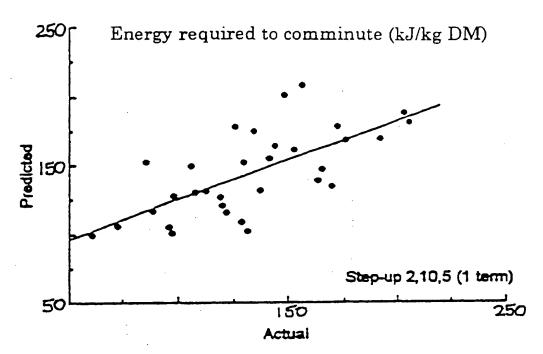
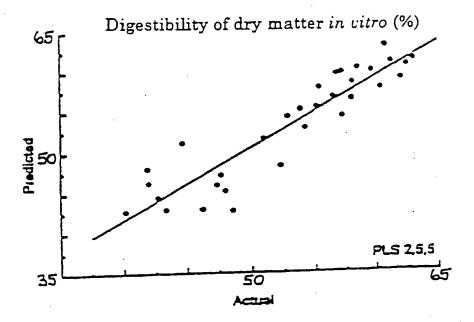
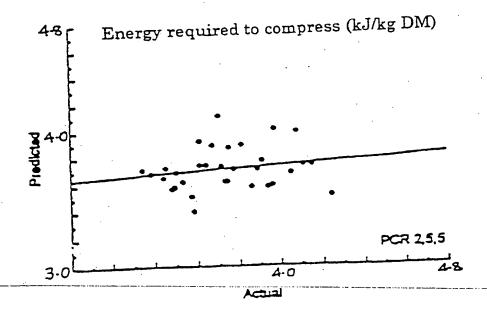
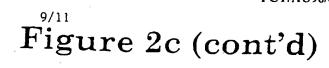


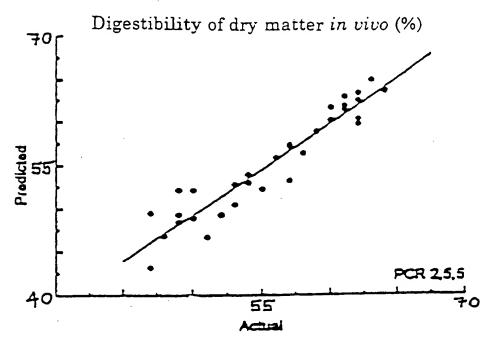
Figure 2c





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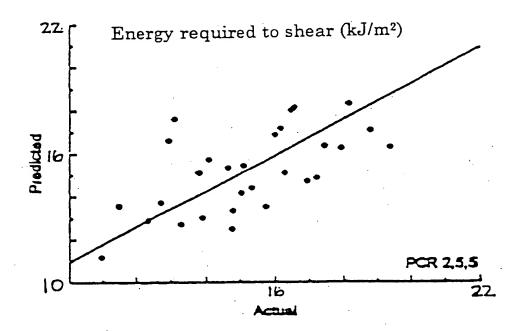
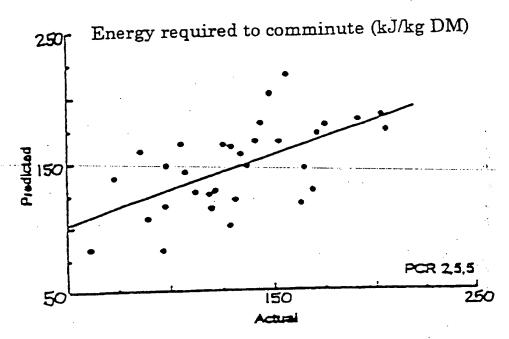
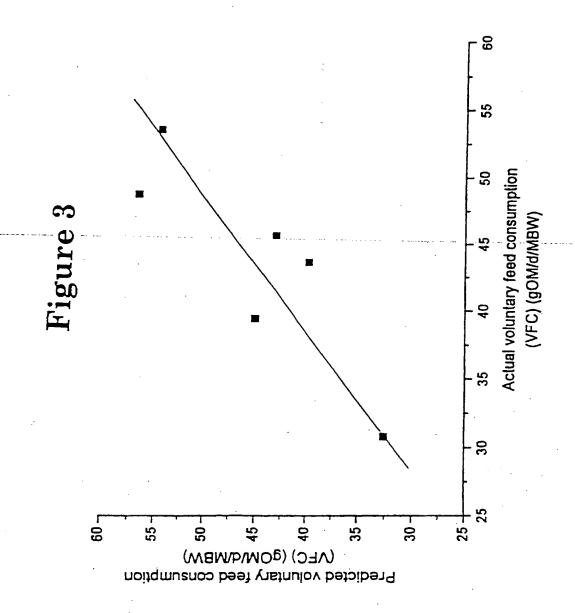


Figure 2c (cont'd)





CLASSIFICATION OF SUBJECT MATTER Int Cl6: G01N 21/35, G01J 3/42 According to International Patent Classification (IPC) or to both national classification and IPC FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: G01N 21/34, 21/35, 33/02, G01J 3/28, 3/42 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU:IPC as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT, JAPIO: (IR or infrared or infra()red), (bond: or energ:) DIALOG: "Science" Supergroup:[(IR or infrared or infra()rcd) and (bond? or energ?) and spectr? and (feed or fodder or hay) DOCUMENTS CONSIDERED TO BE RELEVANT C. Citation of document, with indication, where appropriate, of the relevant passages Relevant to claim No. Category* Animal Feed Science and Technology, Vol. 37 No. 3-4, 1992 Elsevier Science Publishers B.V., Amsterdam, "Influence of growth type and season on the prediction of the metabolisable energy content of herbage by near-infrared reflectance spectroscopy", pages 281-295 by D.I. GIVENS et al. 1-28 See entire document Х Animal Feed Science and Technology, Vol. 51, February 1995, Elsevier Science B.V., "The use of NIRS to predict the chemical composition and the energy value of compound feeds for cattle", pages 243-253 by J.L. de BOEUER et al. 1-28 See entire document Further documents are listed in the continuation of Box C See patent family annex Special categories of cited documents: later document published after the international filing date or "T" priority date and not in conflict with the application but cited to document defining the general state of the art which is "A" understand the principle or theory underlying the invention not considered to be of particular relevance document of particular relevance; the claimed invention cannot "X" earlier document but published on or after the "E" be considered novel or cannot be considered to involve an international filing date inventive step when the document is taken alone document which may throw doubts on priority claim(s) "L" document of particular relevance; the claimed invention cannot or which is cited to establish the publication date of be considered to involve an inventive step when the document is another citation or other special reason (as specified) combined with one or more other such documents, such document referring to an oral disclosure, use, "O" combination being obvious to a person skilled in the art exhibition or other means document published prior to the international filing document member of the same patent family "P" date but later than the priority date claimed Date of the actual completion of the international search Date of mailing of the international search report 26 February 1997 06.03.97 Authorized officer Name and mailing address of the ISNAU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 **GREG POWELL** WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929 Telephone No.: (06) 283 2308 ___

INTERNATIONAL SEARCH REPORT

International Application No.

C (Continua	ti n) DOCUMENTS CONSIDERED TO BE DELEVIOUS	
	TO BE RELEVANT	
Category.*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Proceedings 9th European Poultry Conference, Glasgow, UK, 7-12 August 1994: Volume 2. Symposia papers, published by WPSA, UK, "Current status of near infrared (NIR) spectroscopy in Australia for predicting metabolisable energy of poultry feeds", pages 106-109 by P.C. FLINN et al.	
X	See entire document	1-28
x	Agri-Practice, Vol. 12, No. 3, May/June 1991, Veterinary Practice Pub. Co., USA, "Forage Analyses for Dietary Diagnosis and Management", pages 29-32 by B. ANDERSON et al. See entire document	1-28
x	Bulgarian Journal of Agricultural Science, Vol. 1, No. 1, 1995, Agricultural Academy of Bulgaria, "Estimation of Composition, Digestibility and Feeding Value of Forages by Near Infrared Reflectance Spectroscopy. II. Estimation of Energy Value and Protein Value of Forages" pages 35-44 by S.L. ATANASSOVA et al. See entire document	
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P,A	WO 96/24843 A (WOLFKING DANMARK A/S) 15 August 1996 See page 9, lines 22-24 See page 11 line18 - page 14 line 6	1-28
	See page 16 line 28 - page 17 line 22 See page 18 line 13 - page 20 line 21 See Examples	
1	Derwent Abstract Accession No. 93-180660/22, Class S03, SU 1739284 A1 (UNIV DNEPR) 7 June 1992 See abstract	
	Proceedings of the XVII International Grassland Congress 1993, "Genotypes of dry matured subterranean clover differ in shear energy", pages 592-593 by S.K. BAKER et al. See entire document	
	Proceedings of the XVII International Grassland congress 1993, "Composition of the fractions of dry mature subterranean clover digested in vivo and in vitro" pages 593-595 by L. KLEIN et al. See entire document	
1 '	Patent Abstracts of Japan, E-78, page 1060, JP 53-15890 A (SHIMAZU SEISAKUSHO K.K.) 14 February 1978 See abstract	·
A S	Patent Abstracts of Japan, JP 06-123700 A (HAMAMATSU PHOTONICS KK) 6 May 1994 See abstract	
	Patent Abstracts of Japan, P-393, page 58, JP 60-98335 A (KOGYO GIJUTSUIN (JAPAN)) June 1985 Gee abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No. PCT/AU 96/00776

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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		DK	A 155/95	DK	A 90/96	DK	A 91/96
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